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Indian Standard

# GENERAL REQUIREMENTS AND TESTS FOR RADIO FREQUENCY CABLES

## ( First Revision )

UDC 621·315·21·029·5 : 620·1 : 621·38·038

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**BUREAU OF INDIAN STANDARDS**
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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# *Indian Standard*

# GENERAL REQUIREMENTS AND TESTS FOR RADIO FREQUENCY CABLES

## *( First Revision )*

## 0. FOREWORD

**0.1** This Indian Standard ( First Revision ) was adopted by the Bureau of Indian Standards on 31 December 1987, after the draft finalized by the Wires and Cables for Electronic Equipment Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

**0.2** This standard covers general requirements and tests for radio frequency cables. The requirements for different types of radio frequency cables are covered in the detail specification sheets. In the event of a conflict between this standard and the specification sheet, the latter shall govern.

**0.3** Some general notes on radio frequency coaxial cables are given in Appendix A.

**0.4** In the preparation of this standard, assistance has been derived from the following:

JSS 51100-1974 'Specification for cables, radio frequency'. Directorate of Standardisation, Ministry of Defence.

MIL-C-17F-1983 'Cables, radio frequency, flexible and semi-rigid, general specification for'. Department of Defence, USA.

IEC 96-1-1986 'Radio-frequency cable, Part 1 : General requirements and measuring methods'. International Electrotechnical Commission.

BS 2316 ( Parts 1 and 2 )-1968 'Specification for radio frequency cables. Part 1 General requirements and tests. Part 2 British Government Service requirements'. British Standards Institution.

**0.5** For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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*Rules for rounding off numerical values ( *revised* ).

## 1. SCOPE

**1.1** This standard covers flexible and semi-rigid radio frequency cables with solid and semi-solid dielectric cores, with single, dual and twin inner conductors, primarily intended for use as transmission lines to conduct energy in a simple power transfer continuously or intermittently.

NOTE — In general, these cables are designed for low-loss, stable operation from the relatively low frequencies through the higher frequencies in the microwave and radar regions of the frequency spectrum. These cables are mainly used as connections to equipment or systems and for their inter-connection cables may also be used as circuit elements, delay lines or impedance matching devices.

### 1.1.1 *Cable Types*

**1.1.1.1** *Flexible, coaxial single conductor* — A flexible coaxial cable is constructed of a single inner conductor covered by a flexible low-loss RF dielectric core material which is then surrounded by a braided outer conductors, with the whole covered by a protective covering. In some cases, this is covered by an extra braided armour for use in extremely abusive applications. Each element of the cable is designed to contribute to the requirements of the finished product.

**1.1.1.2** *Semi-rigid, coaxial single conductor* — Semi-rigid coaxial cables are constructed of a single inner conductor covered by a flexible low-loss RF dielectric core material, which is then surrounded by a solid, continuous, metallic outer conductor.

**1.1.1.3** *Two-conductor* — Individual dielectric cores of two-conductor cables shall meet the requirements of solid or semi-solid dielectric cores. One strand of one of the inner conductors shall be coded for identification and shall be visible without disturbing the stranding. That is, if all the strands of the innner conductors are coated, then one strand shall be bare; or if all of the strands are bare, then one strand shall be coated.

a) *Twin* — Twin cables shall be constructed of individual inner conductors within individual dielectric cores, within a common outer conductor or may have individual inner conductors within a common outer core that may be filled-to-round.

b) *Dual* — A dual cable shall be constructed of individual coaxial cables enclosed within a common outer conductor.

**1.1.1.4** *Triaxial* — Triaxial cables are constructed the same way as regular coaxial cables except for an additional interlayer of dielectric material over the outer conductor, over which is laid an extra shield, with the whole covered by a protective covering.

## 2. TERMINOLOGY

**2.0** For the purpose of this standard, the following definitions, in addition to those given in IS : 1885 ( Part 32 )-1971* shall apply.

**2.1 Type Tests** — Tests carried out to prove conformity with the requirements of this standard. These are intended to check the general quality and design of a given type of radio frequency cable.

**2.2 Acceptance Tests** — Tests carried out on samples selected from a lot for the purpose of acceptance of the lot.

**2.3 Routine Tests** — Tests carried out on each sample to check the requirements which are likely to vary during production.

## 3. TYPE DESIGNATION

**3.1** RF cables shall be designated by the following code:

a) The letter 'R' representing 'radio frequency';

> Note — While marking on the cable, this shall be followed by letter either 'C' or 'P' indicating commercial grade or professional grade cable respectively.

b) A number giving the rated characteristic impedance;

c) A whole number corresponding approximately to the nominal diameter over dielectric in millimetres;

d) A letter representing main type of dielectric according to **4.2.2.1**; and

e) A serial number.

*Example* :

R 50-3-A 01 refers to a radio frequency cable of characteristic impedance of 50 ohms with diameter over dielectric approximately 3 mm, polyethylene insulation and serial No. 01.

## 4. MATERIALS AND CONSTRUCTION

**4.1 Materials** — Unless otherwise specified, the materials for the principal components of the cable shall be as specified herein. When a definite material is not specified, a material shall be used that will enable the finished products to meet the performance requirements of this standard.

**4.2 Design and Construction** — Unless otherwise specified, cables shall be of the design and construction specified herein.

**4.2.1** *Inner Conductors* — The inner conductor shall be solid, braided or helical, bare or coated, as specified. The materials and coatings shall be as specified, in detail specification.

**4.2.1.1** *Solid inner conductors*

a) *Bare copper wire* — Bare copper wire shall be soft or annealed copper wire;

b) *Tin-coated copper wire* — Tin-coated copper wire shall conform to tin-coated, soft or annealed copper wire in accordance with IS : 9567-1980*;

c) *Silver-coated copper wire* — Silver-coated copper wire shall conform to IS : 8080-1976†; except thickness of silver coating shall not be less than 1 micron;

d) *Copper-clad steel wire**— Copper-clad steel wire shall conform to high-strength, 40 percent conductivity, hard-drawn, copper-clad, steel wire;

e) *Annealed copper-clad steel wire* — Annealed copper-clad steel wire shall have the same requirements as for copper-clad steel wire specified in (d) except that it shall be annealed. The tensile strength shall be 345 MN/m$^2$ minimum;

f) *Silver-coated copper-clad steel wire*

g) *Annealed copper-clad aluminium wire* — The thickness of the copper covering shall be 3·5 percent minimum of the wire radius ( 8 to 12 percent by volume ) or 5 percent minimum of the wire radius ( 13 to 17 percent by volume );

h) *Copper-beryllium alloy wire* — Copper-beryllium alloy wire shall be solution-heat-treated half-hard wire. The tensile strength shall be 760 to 930 MN/m$^2$;

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*Electrotechnical vocabulary: Part 32 Cables, conductors and assessories for electricity supply.

*Specification for tin or tin-lead coated copper-wire.

†Specification for silver-coated copper wire.

j) *Annealed-copper-beryllium wire* — Same as in ( h ) except the tensile strength shall be 550 MN/m²;

k) *Silver-coated wire* — Silver-coating over other wire material shall conform to IS : 8080-1976* with proper correction for the density of the base material when the gravimetric reference procedure is used; and

m) *High resistance wire* — High resistance wire shall have a composition of 80 percent nickle and 20 percent chromium. The tensile strength shall be 690 MN/m² minimum.

**4.2.1.2** *Stranded inner conductors* — Stranded inner conductors shall be concentrically stranded. Tensile strength and elongation of conductors shall be tested prior to standing. Conductors shall not be coated after stranding ( no overcoating ). Individual wires before stranding shall meet all the requirements of the basic wires specified in **4.2.1.1**. Diameter tolerances for the completed inner conductor shall be rounded to the next highest 0·02 mm.

**4.2.1.3** *Conductor joints* — Joints in individual strands of a stranded wire shall not be closer together than 5 lay-lengths.

**4.2.2** *Dielectric Cores* — The material used in the dielectric cores specified shall be of uniform thickness consistent with the electrical, environmental, physical, mechanical and dimensional requirements.

a) *Solid dielectric cores* — Solid dielectric cores shall be extruded or tape-wrapped as specified and talc-coated when specified.

b) *Semi-solid ( air-spaced ) dielectric cores* — Semi-solid, air-spaced dielectric cores shall be constructed in such a manner that air spaces are a basic element of the construction.

**4.2.2.1** *Dielectric core types* — The material for the dielectric cores shall be one of the following specified types. The dielectric constant and the dissipation factor shall be consistent with the applicable electrical requirements.

*Type A* — Polyethylene ( PE ) low-density type, MFI 2 according to IS : 10579-1983†.

*Type A-1* — Solid PE.

*Type A-2* — Solid PE coated with the best commercial grade of talc, to prevent sticking between individual components of the cable.

*Type A-3* — Air-spaced PE. One PE filament thread or a braid of more than one filament threads within a tube of solid PE, or spiralled fins of PE between tubes of solid PE.

*Type A-4* — Air-spaced PE. Foamed PE.

*Type A-5* — Conductive PE, carbon black type. The maximum resistance per metre shall be as specified.

*Type D* — Not for future design. Dielectric core shall be a composite of three layers of dielectric materials. Each layer shall make intimate contact with each other, except that the outer layer shall be easily strippable.

*Inner layer* : *Type H* — semiconducting synthetic rubber ( *see* **4.2.2.1** ).

*Middle layer* : *Type H* — insulating synthetic rubber ( *see* **4.2.2.1** ).

*Outer layer* : *Type H* — semiconducting synthetic rubber ( *see* **4.2.2.1** ).

*Type E* — Not for future design. Same as type D except outer layer shall be type Q ( insulated polychloroprene rubber ) which need not be easily strippable.

*Type F* — Polytetrafluoroethylene ( PTFE ).

*Type F-1* — Solid extruded PTFE.

*Type F-2* — Solid PTFE tape wrapped.

*Type F-3* — Air-spaced PTFE perforated tapewrapped.

*Type F-4* — Air-spaced PTFE. One PTFE filament thread or a braid of more than one PTFE filament thread within a tube of tapewrapped PTFE.

*Type F-5* — Air-spaced PTFE, porous tape wrapped.

*Type F-6* — Air-spaced PTFE, expanded tape wrapped.

*Type F-7* — Solid PTFE, coated with a semiconducting material.

*Type G* — Not for future design. Solid mineral material ( such as magnesium oxide) consisting of finely divided particles free from detrimental impurities which shall be packed tightly under high pressure.

*Type H* — Not for future design. Semiconducting synthetic rubber. The volume resistivity of this compound shall be within the range of 100 to 1 000 ohm and coloured black.

*Type J* — Insulating synthetic butyl rubber. Butyl rubber shall be a copolymer of isobutylene and isoprene, coloured grey.

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*Specification for silver-coated copper wire.

†Specification for polyethylene ( PE ) insulation and sheath of telecommunication cables.

*Type M* — Fluorinated ethylene propylene ( FEP ).

*Type M-1* — Solid, extruded FEP.

*Type M-2* — Air-spaced FEP. Foamed FEP.

*Type Q* — Not for future design. Insulating polychloroprene rubber and coloured red.

*Type W* — Not for future design. Insulating synthetic rubber. The material shall have a tensile strength of 3·45 MN/m² minimum and an elongation of 300 percent minimum in 250 mm.

**4.2.3** *Outer Conductors or Extra Shields* — Outer conductors or extra shields shall be braided or solid ( tubular ), as specified.

**4.2.3.1** *Braided outer conductors or shields* — Braids shall be applied with the maximum tension possible so as to prevent loosening or creeping but not to cause broken ends. Braids shall have no irregularities or loose unwoven strands. There shall be no splices of the completed braid. The number of braids and the elements of their construction shall be as specified. The individual strands of the braid shall meet the applicable requirements of the basic wires specified in **4.2.1.1**. Strands may also be made of galvanized steel wires. The percent coverage specified shall be determined in accordance with the formulae shown below:

Percent coverage $= (2F - F^2) \times 100$ percent, $F = \dfrac{NPd}{\sin a}$, $\tan a = \dfrac{2\pi(D + 2d)P}{C}$

where

$D$ = maximum outside diameter of the dielectric core under the braid. In the case of double braid construction, the diameter ( $D$ ) for determining the coverage of the outside braid shall be the outside diameter of the inner braid;

$d$ = diameter of an individual strand of the braid;

$N$ = number of ends ( wire strands ) per carrier;

$C$ = number of carriers ( separated group of ends ) around the diameter of the cable;

$P$ = minimum number of picks per length ( separation points between carriers ) along the length of the cable;

$a$ = smaller angle between longitudinal axis of the cable and the braid wires; and

$F$ = fill or space factor.

For two conductor cables that are not filled-to-around and not twisted.

$$\tan a = \frac{2\pi(D_1 + 2d)P}{C} + \frac{4(D_2 - D_1)P}{C}$$

where

$D_1$ = same as $D$, except the minor diameter; and

$D_2$ = same as $D$, except the major diameter.

*Galvanized steel wire braids* ( *see* IS : 3975-1979* ) — When galvanized steel wire braids are specified, the individual strands shall be soft or annealed low-carbon, steel wires. The tensile strength of the individual strands shall be 345 MN/m² minimum. Tin plate ( hot-dipped ) may be used as an alternate to galvanization.

**4.2.3.2** *Solid ( tubular ) outer conductors* — Solid outer conductors shall be constructed of seamless, metallic tubing, annealed before the final sink.

a) *Copper-tubing outer conductors* — Seamless, copper tubing shall be 99 percent minimum purity.

b) *Aluminium-tubing outer conductors* — Seamless, aluminium tubing shall be 99 percent minimum purity.

c) *Solid outer conductor joints* — Joints shall be within the specified dimensions and tensile strength limits specified for the basic solid outer conductor.

**4.2.4** *Barrier Tapes* — When specified, the barrier tapes shall be applied tightly and ride smoothly over the outer conductor. The barrier tape material shall be of the following type:

*Type FF-2* — PTFE tape wrapped. The PTFE may be reclaimed material. Unless otherwise specified, the tapes shall overlap 50 percent of the width of the tapes.

**4.2.5** *Interlayers* — When specified, the interlayer shall be applied tightly and ride smoothly over the outer conductor. The interlayer material shall be one of the following types:

a) *Type A-1R* — PE, low density type, MFI 2 according to IS : 10579-1983†.

b) *Type C-1* — Not for future design. Braid of cotton tapes of 30 denier/2 ply.

c) *Type K* — Polyethylene-terephthalate tape, fungus-resistant type. Unless otherwise specified, the tapes shall overlap 50 percent minimum of the width of the tapes.

d) *Type L* — Not for future design. Glass fiber tapes filled with, and uniformly coated with silicone rubber on both sides

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*Specification for mild steel wires, strips and tapes for armouring of cables ( *first revision* ).

†Specification for polyethylene ( PE ) insulation and sheath of telecommunication cables.

and properly cured. Curing may be accomplished after applying the tapes to the conductor. The tapes shall be held from unwinding by being self-bounding, by using a silicone rubber adhesive or by means of binder over the insulating tapes.

e) *Type U-1* — Not for future design. Urethane elastomer tape.

f) *Type R-1* — Not for future design. Rubber-filled tape.

4.2.6 *Jackets ( Sheaths )* — The jacket material shall be tough, flexible and non-hygroscopic. The jacket shall cover the cable tightly and evenly in a manner consistent with the physical, mechanical, environmental and dimensional requirements. Colour shown is for outer surface of jacket. The jacket material shall be one of the following types, unless otherwise specified ( *see* **3.1** ).

a) *Type I* — Non-professional grade general purpose PVC with a barrier tape.

b) *Type IIa* — Non-contaminating type of medium-low-temperature. Plasticised or compounded, polyvinylchloride or polyvinylchloride-acetate, and coloured black.

c) *Type IIIa* — Not for future design. Polyethylene conforming to type 03C of IS : 10579-1983*, weather-resistant type, and coloured black.

d) *Type IV* — Polychloroprene rubber, medium-low-temperature type and coloured black.

e) *Type V* — Fibreglass braids of the number specified. The braids shall be impregnated with a silicone-base varnish, and oven-baked. The glass fibers shall be coloured brown.

f) *Type VI* — Not for future design. Silicone-rubber-polyester fiber construction. The inner element shall be a single braid of fibreglass impregnated with a silicone-base varnish, under an extruded or tape-wrapped layer of silicone rubber, and the whole thoroughly cured. As an alternate, the inner construction may be a wrap( s ) of silicone rubber impregnated fibreglass tape, which shall be fused during processing. Over either construction, there shall be a protective braid of polyester fibre impregnated with a high temperature fluorocarbon lacquer, and coloured orange.

g) *Type VII* — Polytetrafluoroethylene ( PTFE ), coloured white.

h) *Type VIIa* — Extruded PTFE.

j) *Type VIIb* — PTFE tape wrapped. There shall be two wraps of unsintered tape applied in opposite directions with an overlap of 50 percent minimum of the width of the tapes, and the whole fused during processing.

k) *Type VIII* — Not for future design. Polychloroprene rubber, low-temperature type and coloured black.

m) *Type IX* — Extruded fluorinated ethylene propylene ( FEP ), transparent enough to permit the reading of marking tape through the jacket.

n) *Type X* — Extruded copolymer of ethylene and tetrafluoroethylene ( ETFE ).

p) *Type XI* — Extruded copolymer of ethylene and chlorotrifluoroethylene E-CTFE.

q) *Type XII* — Low-temperature, heat and weather resistant polyurethane thermoplastic elastomer.

r) *Type XIII* — Perfluoroalkoxy ( PFA ) having a tensile strength of 20 MN/m$^2$ and a minimum elongation of 275 percent.

4.2.7 *Armour* — Metal armouring shall be of a braid construction that is rugged, tough and flexible.

a) *Braid* — Individual braid wires shall be of aluminium-alloy. The diameter shall be 0·30 ± 0·01 mm and the tensile strength shall be 360 MN/m$^2$ minimum, before application onto the cable. The percent coverage shall be 88 percent minimum. The formulae shown in **4.2.3.1** shall be used to determine the percent coverage of the braid construction.

b) *Paint* — Armour stall be covered with an aluminium paint, paste form, and coloured light green.

4.2.8 *Workmanship* — All cables shall be manufactured and processed in such a maner as to be uniform in quality and shall be free from any burrs, die marks. Chatter marks, foreign material and other defects that will affect life, serviceability or appearance. Workmanship shall be such as to enable the cable to meet the applicable requirements of this standard.

## 5. PACKING AND MARKING

**5.1 Packing** — RF cable shall be supplied either on reels or in coils suitably packed and labelled.

**5.2 Marking** — RF cable shall be marked with the following information:

a) Manufacturer's name or trade-mark;

b) Type designation; and

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*Specification for polyethylene ( PE ) insulation and sheath of telecommunication cables.

c) Year of manufacture.

NOTE — Alternatively, manufacturer's identification thread and year of manufacture thread may be used for ( a ) and ( c ).

**5.2.1** The marking shall be done in such a manner as not to permanently indent, deform or otherwise damage the jacket or outer covering. The marking shall be visible and legible from the outside of the cable, except for armoured cables. The marking shall be legible after the ageing stability and stress crack resistance tests.

The following details shall apply:

a) *Armoured cables* — Armoured cables shall be marked at intervals not exceeding 15 cm by inserting a suitably printed tape under the armour or jacket provided the marking is legible after the cable construction is completed. When the armour is added to a cable that has been previously marked with its unarmoured type designation, the marking tape shall be inserted between the armour and the jacket only. When cables are so double marked, the marking on or under the jacket shall be disregarded.

b) *Unarmoured cables*

   1) Types IIa, IIIa, IV, VI, and VIII jackets shall be surface marked at intervals not exceeding 50 cm. Cables with type V jackets shall be marked with tapes. Cables with Type VI, X and XI jackets may be optionally marked with tapes.

   2) Type IX jackets shall be marked at intervals not exceeding 15 cm. Cables with Type IX jackets, whose nominal outside diameter is 4 mm or less, need not be marked.

   3) Cables, twin axial, which do not have a requirement for fill-to-round, may be marked with a tape under the jacket regardless of jacket type.

c) Semi-rigid cables and unarmoured cables with Type VII jackets need not be marked.

**5.2.2** RF cable may also be marked with the Standard Mark.

NOTE — The use of the Standard Mark is governed by the provisions of the Bureau of Indian Standards Act 1986 and the Rules and Regulations made thereunder. The Standard Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well defined system of inspection, testing and quality control which is devised and supervised by BIS and operated by the producer. Standard marked products are also continuously checked by BIS for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

## 6. TESTS

### 6.0 General

**6.0.1** Unless otherwise specified, all tests shall be performed under the following conditions [ *see* IS : 9000 ( Part 1)-1977* ]:

a) Temperature : 15 to 35°C.

b) Relative humidity : 45 to 75 percent.

c) Atmospheric pressure : 86 to 106 kPa.

**6.0.2** Test parameters given in the tests are not to be assumed as the cable operating conditions, temperatures or limits. Methods of tests given in the standard shall be the only acceptable method, unless an alternate method has been agreed to by the manufacturer or the purchaser. The test methods described are the preferred methods and shall be the referee method in cases of dispute.

**6.1 Type Tests** — The schedule of type tests is given in Table 1.

TABLE 1 TYPE TESTS

| TESTS | NO. OF SPECIMENS TO BE TESTED | METHOD OF TEST, CLAUSE REF |
|---|---|---|
| *Group I* | | |
| In-process inspection | Entire sample | 6.5 |
| Continuity | Entire sample | 6.6 |
| Spark test | Entire sample | 6.7 |
| Voltage withstanding | Entire sample | 6.8 |
| Insulation resistance | Entire sample | 6.4 |
| Visual and mechanical inspection | Entire sample | 6.4 |
| Physical dimensions | Entire sample | 6.4 |
| Marking | Entire sample | 6.4 |
| Workmanship | Entire sample | |
| *Group II* | | |
| Corona extinction voltage[1] | 1 | 6.9 |
| Characteristic impedance | 1 | 6.10 |
| Attenuation ( insertion loss )[1] | 2 | 6.11 |
| Structural return loss[1,2] | 2 | 6.12 |
| Capacitance[1] | 2 | 6.13 |
| Capacitance stability[1] | 1 | 6.14 |
| Capacitance unbalance[3] | 1 | 6.15 |
| Transmission unbalance[2,3] | 1 | 6.16 |
| Mechanically induced noise | 1 | 6.17 |
| voltage[2,4] | 1 | 6.18 |
| Time delay[1,2] | 2 | 6.18 |
| Ageing stability[5] | 4 | 6.19 |
| Stress-crack resistance[1,2] | 4 | 6.20 |
| Outer conductor integrity[2,5] | 4 | 6.21 |
| Screening efficiency[1] | 1 | 6.22 |
| Cold bend[2,9] | 1 | 6.23 |
| Flow[1] | 1 | 6.24 |

(*Continued*)

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*Basic environmental testing procedures for electronic and electrical items: Part 1 General.

TABLE 1 TYPE TESTS — *Contd*

| TESTS | NO OF SPECIMENS TO BE TESTED | METHOD OF TEST, CLAUSE REF |
|---|---|---|
| Dimensional stability[1] | 1 | 6.25 |
| Contamination[2,8] | 1 | 6.26 |
| Bendability[2,6] | 2 | 6.27 |
| Flammability[1,2] | 1 | 6.28 |
| Resistance to fluids[2] | 1 | 6.29 |
| Solderability | 1 | 6.30 |
| Weight[2] | 1 | 6.31 |

[1] When specified in detail specification.
[2] When specially required.
[3] Applicable to two-conductor cables.
[4] Applicable to low noise cables.
[5] Not applicable to semi-rigid or cables with Type IX jackets.
[6] Applicable to semi-rigid cables.
[7] Not applicable to time delay or braided inner conductor cables.
[8] Applicable to Type IIa jackets.
[9] Not applicable to semi-rigid cables.

**6.1.1** *Sample* — The sample of each cable type submitted for qualification inspection shall be of sufficient length to perform all the applicable type tests.

**6.1.2** The entire sample shall be subjected to the tests of Group I. The specimen length shall be cut from each sample as required, and subjected to tests of Group II.

**6.1.3** *Failure* — One or more failures shall be cause for refusal to grant type approval.

**6.2 Routine Tests** — The schedule of routine tests is given in Table 2.

TABLE 2 ROUTINE TEST

| TEST | METHOD OF TEST, REF TO CLAUSE |
|---|---|
| In process inspection | |
| Continuity | 6.5 |
| Spark test | 6.6 |
| Voltage withstand | 6.7 |
| Insulation resistance | 6.8 |
| Visual and mechanical inspection | 6.4 |
| Physical dimensions | 6.4 |
| Marking | 6.4 |
| Workmanship | 6.4 |

**6.3 Acceptance Tests** — The schedule of acceptance tests is given in Table 3. The acceptance tests shall be performed on samples that have already passed the routine tests.

**6.3.1** *Inspection of Product for Delivery* — Inspection of product for delivery shall consist of groups A and B inspections.

**6.3.1.1** *Unit of product* — A unit of product shall be 1 500 m of cable of the same type designation. If a production run is less than 1 500 m, then the quantity produced shall be one unit of product.

*Inspection lot* — The inspection lot shall consist of the number of units of product, offered for inspection at one time. All of the units of product in the inspection lot submitted shall have been produced during the same production period with the same materials and processes.

*Sample unit* — A sample unit shall be a unit of product selected at random from the inspection lot without regard to quality.

*Sample unit size* — Unless otherwise specified, the sample unit size shall consist of that number of sample units required by the inspection lot size, as determined by the sampling plans in IS : 10673-1983*.

*Specimen* — A specimen shall be an individual length of cable cut from the sample unit.

**6.3.1.2** *Group A inspection* — Group A inspection shall consist of the inspections specified in Table 3.

*Sampling plan* — Statistical sampling and inspection shall be in accordance with IS : 10673-1983* for general inspection level II. The acceptable quality level ( AQL ) shall be as specified in Table 3.

TABLE 3 ACCEPTANCE TESTS

( *Clauses* 6.3 *and* 6.3.1.2 )

| TEST | METHOD OF TEST, REF TO CLAUSE | AQL (PERCENT DEFECTIVE) | INSPECTION LEVEL |
|---|---|---|---|
| *Group A* | | | |
| Visual and mechanical inspection | 6.4 | 1 | II |
| Physical dimensions | 6.4 | | |
| Marking | 6.4 | | |
| Workmanship | 6.4 | | |
| Characteristic impedance | 6.10 | | |
| Attenuation ( insertion loss ) | 6.11 | | |
| Structural return loss[1,2] | 6.12 | | |
| *Group B* | | | |
| Corona extinction voltage[1] | 6.9 | 4 | S-3 |
| Capacitance | 6.13 | | |
| Capacitance unbalance[1] | 6.15 | | |
| Transmission unbalance[1,2] | 6.16 | | |
| Mechanically induced noise voltage[1,2] | 6.17 | | |
| Time delay[1,2] | 6.18 | | |
| Cold bend[2,3] | 6.23 | | |
| Contamination[2,4] | 6.26 | | |
| Resistance to fluids[2] | 6.29 | | |
| Solderability | 6.30 | | |
| Weight[2] | 6.29 | | |

[1] As applicable.
[2] When specially required.
[3] Not applicable to semi-rigid cables.
[4] Applicable to IIa jackets.

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*Sampling plans and procedures for inspection by attributes for electronic terms.

6.3.1.3 *Group B inspection* — Group B inspection shall consist of the inspection specified in Table 3.

*Sampling plan* — The sampling plan shall be in accordance with IS : 10673-1983* for special inspection level S-3. The sample size shall be based on the inspection lot size from which the sample was selected for Group A inspection. The AQL shall be as shown in Table 3.

**6.4 Visual and Mechanical Examination** — The cable shall be examined to verify that the design, construction, physical characteristics and dimensions marking, and workmanship are in accordance with the application requirements ( *see also* **4.2.8** and **5** ).

*Requirement* — The visual and mechanical characteristics shall be as specified in detail specification.

**6.4.1** *Diameter Measurements*

a) *All components, except the dielectric core of semi-rigid cable* — Measurements shall be made on a suitable length ( 300 mm minimum ) of cable taken from the end of the sample unit. Inner components shall be made accessible by stripping and removing the outer components carefully so as not to nick, cut, cold-work or otherwise, damage the component to be measured. Four points for measurement shall be located 75 to 100 mm apart along the specimen length.

   Measurements shall be made at each point in two mutually perpendicular planes so that a total of eight measurements are performed on each specimen. Measurements shall be made with a micrometer caliper or any other instrument of equal accuracy.

b) *Dielectric core of semi-rigid cables* — The outer diameter of the dielectric core shall be determined by measuring the inner diameter of the solid outer conductor. Measurements shall be made on four specimens, each 12 mm approximately in length, taken from the end of the sample unit. The specimens shall be cut squarely and carefully deburred. Measurements shall be made by means of plug gauges or an adjustable plug hole gauge and a micrometer or any other instrument of equal accuracy.

*Requirement* — The diameter measurements shall be as specified in detail specification.

**6.4.2** *Out-of-Roundness of Jacket Measurements*+ — When specified, the out-of-roundness of the jacket shall be monitored on a continuous production basis, and the jacket diameter shall be as specified. The out-of-roundness measurements shall be permanently recorded with a device capable of producing continuous graphic records. Two recordings shall be made, as nearly simultaneously as possible, of the outside diameter 90° apart and a point in the manufacturing process where further dimensional change will not occur. The recordings shall be permanent and reproducible by a common commercial process. The technique used ( including the detector, recorder and associated components ) shall have a response capable of recording changes in the diameter with a sensitivity of 0·02 mm along the length of cable at whatever speed the cable is travelling. The strip chart response time shall be compatible with the remainder of the system. The pen traverse shall be large enough to distinguish changes of diameter of 0·02 mm. The chart speed relative to the cable speed shall be such that the recording shall be identifiable to within 60 cm of the point on the cable length measured. Each metre of cable shall be represented by not less than 5 mm of recording paper.

NOTE — Alternatively, a suitable optical method may be employed.

*Requirement* — The out-of-roundness of jacket diameter dimensions shall be as specified in detail specification.

**6.4.3** *Eccentricity of Inner Conductor* — Not applicable to cable that have the inner conductor formed over an inner conductor support.

**6.4.3.1** *Procedure* — Four specimens, each 25 mm approximately in length, shall be cut from the end of the sample unit. The outer components of the cable shall be removed down to the dielectric core. The ends of the specimen shall be cut squarely and carefully deburred. The eccentricity, in terms of displacement of length, shall be measured with a machinist's microscope or a comparator or any other instrument capable of yielding a resolution of at least 0·002 mm. At spacings approximately 45° apart around the periphery of the inner conductor, measurements shall be taken of the dielectric wall thickness. The thickest measurement ( $T_{Max}$ ) and the thinnest measurement ( $T_{Min}$ ) shall then be used to compute the displacement using the following formula:

$$\text{Percent eccentricity} = \frac{T_{Max} - T_{Min}}{\text{Measured diameter of core}} \times 100$$

The percent eccentricity of the inner conductor shall be within the specified requirements.

**6.4.3.2** *Alternate method* — As an alternate method of measurement that is more applicable for determining the eccentricity of the inner conductor of a semi-rigid cable, lay the sample in a V-shaped trough to which a dial indicator has been rigidly fastened in such a manner as to preclude movement of the indicator with respect to the trough, and to allow a reading of the inner conductor position with respect to the outer surface of the cable. Four specimens, each approximately 150 mm long, shall be cut from the end of the sample unit. Prepare the specimen by exposing approximately 6 mm of the inner conductor at one end of each specimen. The dial indicator shall be capable of yielding a resolution of at least 0·002 mm. The specimen shall be slowly rotated in the trough and the difference in dial indicator readings shall be noted through a rotation of 360°. Care shall be taken to avoid bending the inner conductor during the rotation operation. The difference in the dial indicator reading is the total indicator reading ( TIR ) from which the percent eccentricity may be computed using the following formula:

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*Sampling plans and procedures for inspection by attributes for electronic terms.

+When specially required.

$$\text{Percent eccentricity} = \frac{\text{Difference in dial indicator readings}}{\text{Measured diameter of core}} \times 100$$

*Requirement* — The displacement of inner conductor shall not exceed 10 percent of the core radius, unless otherwise specified.

**6.4.4** *Adhesion of Conductors**

**6.4.4.1** *Specimen*

a) Two specimens of each cable shall be cut from the end of the sample unit. Each specimen shall be prepared as shown in Fig. 1A and 1B. Stripping shall be done carefully. For semi-rigid cables, not more than 6 mm of material shall be removed at one time.

b) The adhesion to conductors test shall be performed with a tensile tester and a test fixture such as shown in Fig. 2A and 2B. The diameter of the hole in the test plate shall be 0·100 ± 0·025 mm larger than the diameter of the applicable inner conductor or dielectric core. The inner conductor or dielectric core extending through the test plate hole shall be pulled with a constantly increasing force at a rate not to exceed 12·5 mm per minute. Avoid sudden pulls and jerking. Conductor adhesion shall be defined as the highest tensile tester reading obtained when the conductor-to-core bond is broken. In performing this test, physical handling of the specimen shall be kept to a minimum to avoid specimen degradation.

*Requirement* — The adhesion of the inner conductor to the dielectric core and the adhesion of the dielectric core to the outer conductor shall be as specified in detail specification.

**6.5 Continuity** — To establish continuity, 25 volts dc maximum shall be applied to both ends of each conductor and shield of the cable through an appropriate indicator such as an ohmmeter light or buzzer. The test voltage may be applied to the conductors and shields individually or in series.

*Requirement* — Each conductor and shield shall be continuous.

**6.6 Spark Test** — Not applicable to semi-rigid cables or to cables with Type V and Type VI jackets. The specimen shall be tested for jacket spark. A test voltage as specified at a frequency between 40 and 60 Hz or 3·0 ± 0·5 kHz shall be applied between the outermost braid or shield and the outer surface of the jacket. Either 50 Hz or 3 kHz is acceptable. In the event of conflict, the 50 Hz test will be the governing test.

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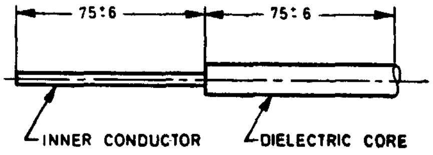
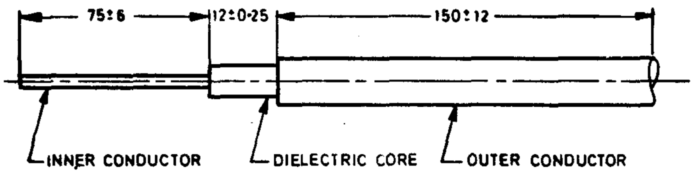
*When specially required.



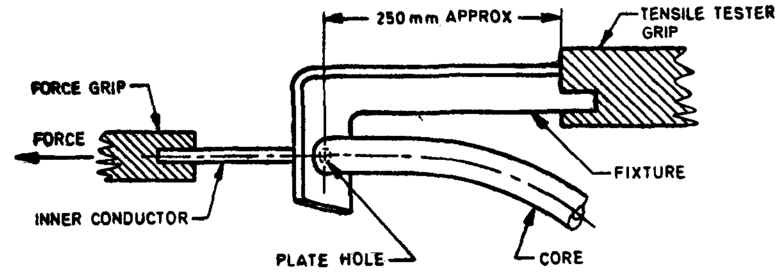
1A Stripping Dimensions for Flexible Cables



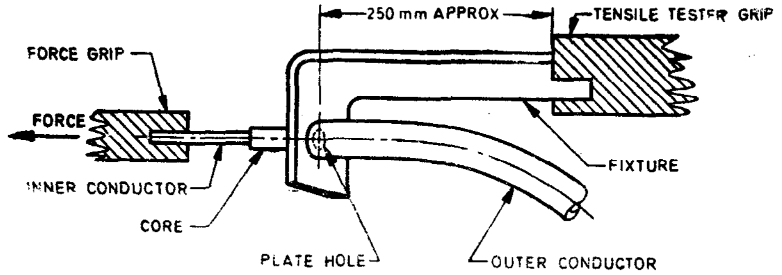
1B Stripping Dimensions for Semi-rigid Cables

All dimensions in millimetres.

FIG. 1 STRIPPING DIMENSIONS FOR ADHESION OF CONDUCTORS



2A Typical Test Fixture for Use with Flexible Cables



2B Typical Test Fixture for Use with Semi-rigid Cables

FIG. 2 TYPICAL TEST FIXTURE FOR ADHESION OF CONDUCTORS

*Requirement* — There shall be no breakdown, flashover or sparkover.

**6.7 Voltage Withstanding** — The test shall be applied on completed cable only. An alternating voltage of specified value at a frequency between 40 and 60 Hz, and sinusoidal waveform shall be applied. The rate of increase of the test voltage shall not exceed 2 kV/s. The test voltage shall be maintained for 1 minute as follows:

a) *For Coaxial Cables* — The test voltage shall be applied between the inner and the outer conductor with the outer conductor grounded.

b) *For Triaxial Cables* — In addition to (a), 500 V dc shall be applied between the outer conductor and the extra shield with the extra shield grounded.

c) *For Two-conductor Cables* — The test voltage shall be applied between the two inner conductors. In addition, the test voltage shall be applied individually between each inner conductor and the outer conductor with the outer conductor grounded.

*Requirement* — There shall be no breakdown, flashover or sparkover.

**6.8 Insulation Resistance** — The specimen shall be measured with an apparatus suitable to verify compliance with the applicable detail specification requirement. The following details shall apply:

a) Unless otherwise specified, the measurement error, including the error of the test voltage source, the error of the indicating circuit and the error in measurement of the mechanical specimen lengths shall not exceed ±15 percent.

b) The voltage shall be 500 ± 500 V dc and the polarity shall be such that the outer conductor is at ground potential.

c) Measurements shall be made between the inner and outer conductors.

d) Unless otherwise specified, readings shall be taken immediately after an uninterrupted 2-minute electrification period. However, a stable or an increasing reading indicating compliance with the specification requirement obtained before elapse of the 2-minute electrification period shall be acceptable.

e) The insulation resistance of the test specimen shall be calculated from the formula.

$$R = \frac{M \times L}{1\,000}$$

where

$R$ = insulation resistance for 1 000 metres in megohms;

$M$ = indicator reading in megohms; and

$L$ = test specimen length in metre, measured between outer conductor ends.

f) The measurement shall be made at ambient temperature. In case of dispute, the measurement may be repeated at 20°C.

*Requirement* — The insulation resistance per 1 000 m shall be as specified in detail specification.

**6.9 Corona Extinction Voltage** — The cable test specimen shall be subjected to a gradually increasing sinusoidal voltage until a detector indicates a sustained corona discharge. The following details shall apply:

a) The sensitivity of the detection equipment shall permit observation of corona of five picocoulombs or less.

b) The cable specimen shall be from 0·5 to 1·5 m in length. The ends of the cable shall be made corona-free. A suggested method for making the cable ends corona-free is shown in Fig. 3 ( *see* **6.7** ).

c) After the cable preparation, connect the cable test specimen to a voltage source. Both ends may be immersed in insulating oil to prevent corona discharge at the ends. A suggested method for immersion in oil is given in Fig. 4.

d) The test voltage shall be applied at room ambient conditions. The frequency of the test voltage shall be between 48 and 62 Hz.

e) Slowly increase the test voltage from 40 to 60 Hz, until the detector indicates a sustained corona discharge or reaches two times the specified corona extinction voltage.

f) If sustained, corona discharge is indicated, the voltage shall then be decreased slowly until the corona extinction point is observed. The corona extinction voltage is defined as the voltage at which sustained discharge ceases. If sustained corona has not been observed at two times the specified corona extinction level, the requirement is considered to have been satisfied.

g) When specified, the corona extinction voltage test shall be performed at the specified altitude equivalent reduced pressure.

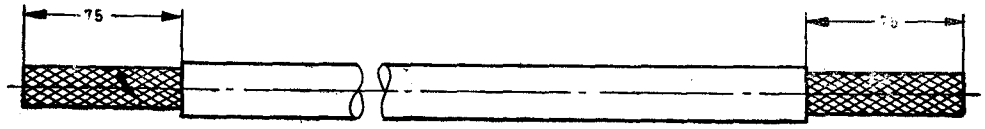
*Requirement* — The corona extinction voltage shall be not less than that specified in the detail specifications.

**6.10 Characteristic Impedance**

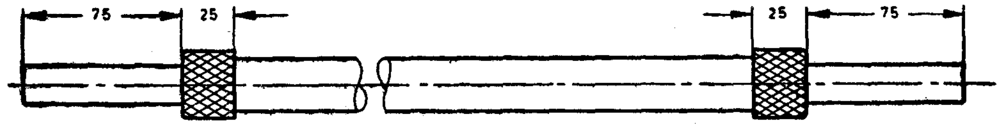
**6.10.1** *Specimen* — The specimen shall be 3 m minimum or 2 dB maximum at 3 GHz, whichever is the shorter.

**6.10.2** *Procedure* — The specimen shall be prepared for testing by assembling appropriate connections to the cable ends. The equipment shall include a time domain reflectometer ( TDR ). The rise time of the TDR shall be 150 picoseconds or less, and the vertical sensitivity of the system shall provide for a minimum resolution of one major scale division. A precision air-line of the same nominal characteristic impedance as the specimen shall be connected between the TDR and the connector-cable assembly. The characteristic impedance of the specimen shall then be measured compared to the precision air-line. The connector-cable assembly shall then be turned end-to-end and the measurement

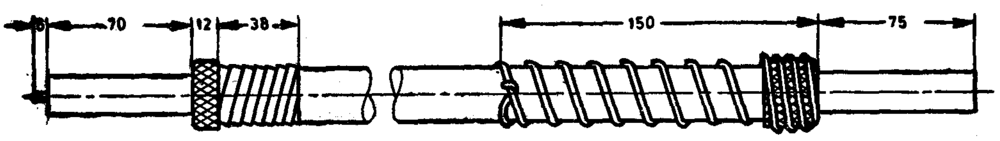
Step 1 : Suggested length of specimen is 915 mm.



Step 2 : Remove 75 mm of jacket material from each end.



Step 3 : Roll back the braid over the jacket and trim as shown. Be careful to avoid breaking any strands. Trim the braid edges neatly to 25 mm lengths.



Step 4 : Trim one end of the specimen to the dimensions shown and cover the braid edge and jacket with a plastic tape as shown. Wrap 0·8 mm dia copper grounding wire tightly over the braid.

All dimensions in millimetres.

FIG. 3 SUGGESTED METHOD FOR MAKING CABLE ENDS CORONA FREE

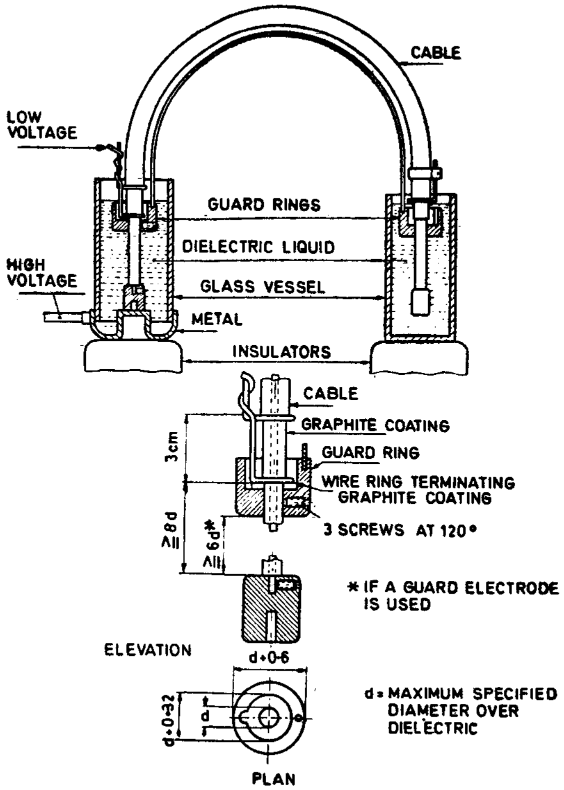


FIG. 4 CABLE MOUNTING AND METHOD OF TERMINATION

repeated. For cables of other than 50 and 75 ohms characteristic impedance, where precision air-lines, loads, or proper impedance measuring equipment are not available, the characteristic impedance may be determined by calculation from the capacitance measurement determined (*see* **6.13**) and the velocity of propagation measurement determined, using the following formula:

$$Z_0 = \frac{3\,333 \times 10^2}{\text{Velocity of propagation ( percent )} \times \text{capacitance ( pF/m )}}$$

*Requirement* — The maximum characteristic impedance shall not exceed the higher value, and the minimum shall not be less than the lower value specified in detail specification.

### 6.11 Attenuation ( Insertion Loss )

**6.11.1** *Specimen* — When testing according to **6.11.1.1**, the specimen shall be of sufficient length to exhibit not more than 26 dB attenuation at the highest swept-frequency, and not less than 3 dB attenuation at the lowest swept-frequency required. If the required frequency range is such that one specimen cannot fulfil this requirement, an additional specimen length shall be used. When testing according to **6.11.1.2**, the specimen length shall be as specified therein. Suitable connectors shall be attached to both ends of the specimen.

**6.11.1.1** *Procedure ( swept-frequency method )* — A swept-frequency insertion loss technique shall be used to determine the attenuation within the specified frequency range. Figure 5 shows a block diagram of typical equipment to be used for insertion loss measurements. The fixed value attenuator pads shall have a minimum value of 3 dB. The specimen shall be inserted between fixed pads No. 1 and 2. The variable attenuator shall be set so that the attenuator trace for the cable falls completely on the X-Y recorder chart for the sweep range used. A calibration grid shall be established either before or after the attenuation characteristics of the specimen are traced by removing the specimen from the circuit, connecting pad No. 1 to pad No. 2 and then increasing the variable attenuator dB settings in uniform steps for each sweep until a series of calibration lines are drawn across the chart of a sufficient range to cover the attenuation

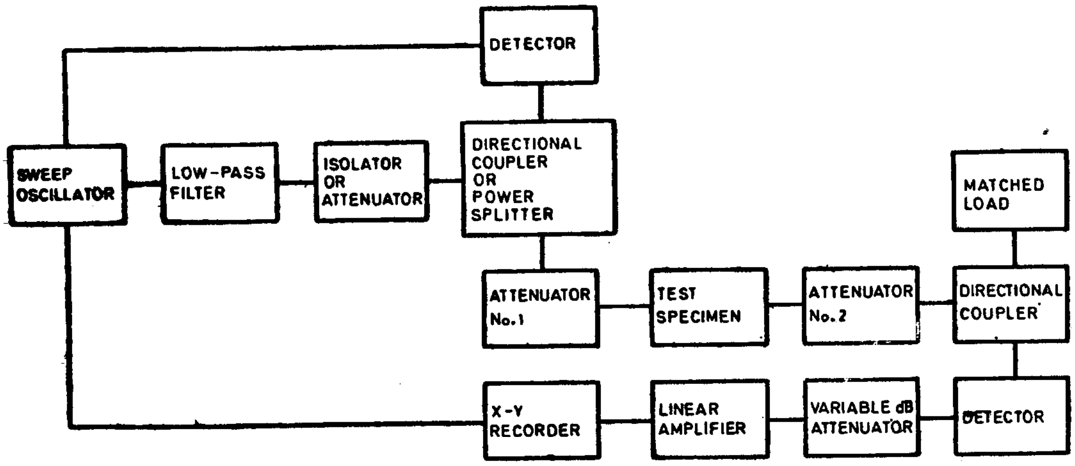
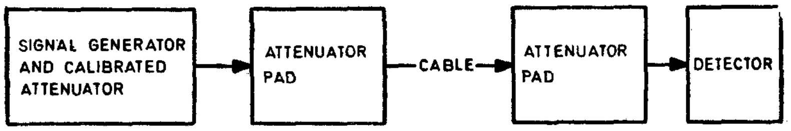


FIG. 5 BLOCK DIAGRAM OF ATTENUATION MEASUREMENT EQUIPMENT

characteristics of the specimen. One of the horizontal calibration lines shall contain frequency marker pips. The value of attenuation of the specimen at any frequency may then be determined from the chart. The attenuation at any frequency shall be expressed by the following formula:

$$\text{Attenuation (dB/100 metre)} = \frac{\text{Measured dB} \times 100}{\text{Specimen length ( metre )}}$$

**6.11.1.2** *Procedure ( single-frequency method )* — The attenuation, expressed in dB per 100 metres, shall be measured at a sufficiently low-power level that the resulting temperature rise will be negligible. An acceptable method for measuring attenuation at a specified frequency is as follows :



In the block diagram shown above, a suitable length of cable with an attenuation of at least 3 dB is inserted between the connectors. The signal generator and calibrated attenuator are adjusted to produce a reasonable indication at the detector, when the detector is tuned. The detector reading is noted, and the calibrated attenuator output level is recorded. The cable under test is then withdrawn and the circuit completed with the connectors ( of a very short length of cable ). With the detector tuned, the calibrated attenuator is readjusted to reproduce the original reading at the detector, and the attenuator output level is again recorded. Attenuation is then computed as follows:

$$A = \frac{100}{L} \text{( difference in calibrated attenuator readings in dB )}$$

where

$A$ = attenuation in dB per 100 metres, and

$L$ = length of cable under test in metres.

For measurements at frequencies of 400 MHz or less, the characteristic impedance of the attenuator pads and connectors shall preferably be the same as that of the cable under test. For measurements at frequencies of 1 000 MHz or above, the attenuator pads, connectors and test cable shall be matched to the same characteristic impedance. Both pads shall be high enough in attenuation value to minimize the error caused by any mismatch of the signal generator and detector. For the majority of measurements, it is recommended that the attenuation of each pad be approximately 10 dB. Tuning stubs may be used in the circuit for impedance-matching purposes. Any other approved method may be used in lieu of that described above.

NOTE — Alternatively, attenuation ( insertion loss ) may be measured with a network analyzer.

*Requirement* — The attenuation shall not exceed the values shown on the applicable curve or at the specified frequencies, whichever is specified. When specification sheets contain a curve and tabulated values for attenuation, the curve represents the requirements. The tabulated values are for reference only.

### 6.12 Structural Return Loss*

**6.12.1** *Procedure* — The specimen shall be of sufficient length to exhibit not less than 3 dB attenuation at the lowest swept-frequency required. If the required frequency range is such that one specimen cannot fulfil this requirement, then an additional specimen shall be used. A swept-frequency, slotted line technique shall be used to determine the structural return loss within the specified frequency range. Suitable connectors shall be attached to both ends of the specimen and the assembly checked with a TDR, that is, capable of producing a step-function rise-time of 150 picoseconds or less. With the far end of the specimen connected to a matched load, the impedance variation exhibited by each connector-cable interface shall not be greater than the maximum impedance variation permitted for the cable itself. Correction curves will be used for other than matched systems. Figure 6 shows a block diagram of typical equipment to be used for the swept measurement of the standing wave ratio ( SWR ). The total SWR excluding the cable of the slotted line connectors and load shall be less than 1·06. A calibration grid shall be established on the X-Y recorder chart terminating the slotted line with a matched load. Starting from zero attenuation, increase the variable attenuator setting in uniform steps with each sweep, until a series of calibration lines sufficient to cover the SWR range of the test assembly is traced on the chart. One of the calibration lines shall contain frequency marker pips and a calibrated narrow band spike, that is, 1 percent wide at 10 MHz to 2 GHz and 20 MHz wide above 2 GHz. Decrease sweep speed until the calibration spike stops growing.

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*When specially required.

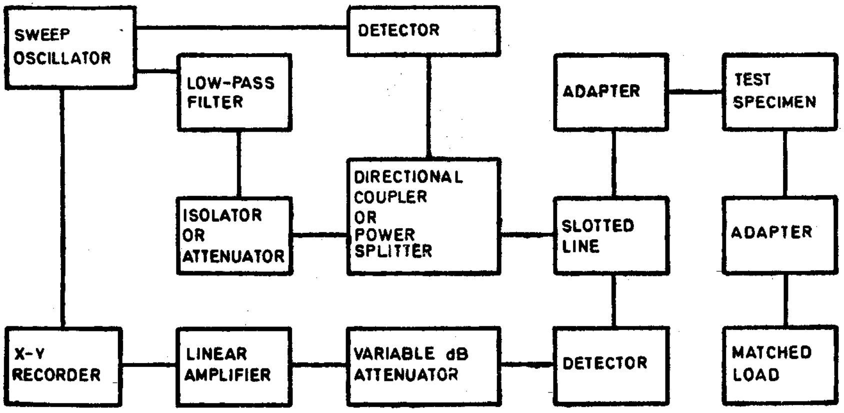

FIG. 6 BLOCK DIAGRAM OF STRUCTURAL RETURN LOSS TEST MEASURING EQUIPMENT

**6.12.2** *Measurements* — To make the SWR measurement insert the cable between the adapters. Set the variable attenuator so that the SWR pattern fails within the calibrated curves. Move the slotted line probe back and forth along the line for at least one-half wavelength at the lowest frequency trace. A minimum of 20 increments shall be used. Then measure the vertical thickness of the envelope ( in dB ) at the frequency of interest and determine the SWR by using the following formula:

$$\text{SWR} = \text{antilog}_{10} \frac{\text{dB}}{20}$$

The structural return loss, in dB, shall be calculated from the SWR as expressed by the following formula:

$$\text{dB ( reflected loss )} = 20 \log_{10} \frac{\text{SWR} + 1}{\text{SWR} - 1}$$

NOTE — Alternatively, structural return loss may be measured with a network analyzer.

*Requirement* — The structural return loss shall be better than the values shown on the applicable curve or over the specified frequency range, whichever is specified in detail specification.

**6.13 Capacitance** — The capacitance, in picofarads per metre, of the specimen shall be measured at 1 kHz, unless otherwise specified. The following details shall apply:

a) The specimen length shall be less than 1/40 wavelength but not less than 1·5 m.

b) *Coaxial Cable* — The capacitance shall be measured between the inner conductor and the outer conductor, with the outer conductor earthed.

c) *Two-conductor Cables* — The capacitance between the two inner conductors shall be measured by a two- or three-terminal technique.

1) *Two-terminal method* — With the outer conductor connected to the ground terminal of the capacitance bridge, the capacitance shall be determined from the following formula:

$$\text{Capacitance} = \frac{2\,(C_a + C_b) - C_c}{4}$$

where

$C_a$ = capacitance between conductor 1 and conductor 2 with conductor 2 connected to the outer conductor.

$C_b$ = capacitance between conductor 2 and conductor 1, with conductor 1 connected to the outer conductor.

$C_c$ = capacitance between conductor 1 and conductor 2 ( when tied together ) and the outer conductor.

2) *Three-terminal method* — The capacitance shall be determined from the following formula:

$$\text{Capacitance} = C_d + \frac{C_e + C_f}{4}$$

where

$C_d$ = capacitance between conductor 1 and conductor 2, with the outer conductor connected to the earth terminal of the capacitance bridge.

$C_e$ = capacitance between conductor 1 and the outer conductor, with conductor 2 connected to earth.

$C_f$ = capacitance between conductor 2 and the outer conductor, with conductor 1 connected to earth.

*Requirement* — The capacitance shall be as specified in detail specification.

**6.14 Capacitance Stability** — The capacitance, in picofarads per metre, shall be measured as specified in **6.13**. The length of the specimen shall be approximately 15 m, except that for cables with solid outer conductors, the length of the specimen shall be approximately 3 m. The specimen shall be subjected to the applicable temperature cycle shown in Table 4, for a total of three cycles. Test temperatures for cables with dielectric cores not listed in Table 4 shall be as specified. Capacitance measurements shall be made initially and after each step.

TABLE 4 TEMPERATURE CYCLING

| STEP | TYPE A DIELECTRIC C TEMPERATURE | TYPE F DIELECTRIC C TEMPERATURE | TIME HOURS |
|---|---|---|---|
| 1 | $+75 \pm 2$ | $+250 \pm 5$ | 4 to 8 |
| 2 | $+25\ ^{+10}_{-5}$ | $+25\ ^{+10}_{-5}$ | 4 minimum |
| 3 | $+40 \pm 2$ | $-55 \pm 2$ | 4 to 8 |
| 4 | $+25\ ^{+10}_{-5}$ | $+25\ ^{+10}_{-5}$ | 4 minimum |

*Requirements* – The capacitance during and after the test shall not have changed from its initial measurement more than the value specified in detail specification.

**6.15 Capacitance Unbalance ( For Two-conductor Cables Only )** — The capacitance, in picofarads per metre, shall be measured as specified in **6.13**. The length of the specimen shall be as specified in **6.13**. The capacitance between the two inner conductors of the two-conductor cable shall be measured by the two- or three-terminal technique as specified in **6.13**. The capacitance unbalance in percent shall be determined from the following formula:

a) *Two-terminal Method*:

$$\text{Capacitance unbalance} = \frac{400\,(C_a - C_b)}{2\,(C_a + C_b) - C_c}$$

b) *Three-terminal Method*:

$$\text{Capacitance unbalance} = \frac{400\,(C_e - C_f)}{4\,C_d + C_e - C_f}$$

*Requirement* – The capacitance unbalance shall not exceed the value specified in detail specification.

**6.16 Transmission Unbalance* ( For Two-conductor Cables Only )**— The transmission unbalance of a two-conductor coaxial cable is defined as the ratio of the absolute magnitude of the vector difference of the voltages across each half of a terminating resistor to one half of the absolute magnitude of the vector sum of the two voltages, expressed mathematically as follows:

$$\text{Transmission unbalance ( TUB )} = \frac{|V_2 - V_1|}{1/2\,|V_2 + V_1|} \times 100 \text{ percent}$$

where

TUB = transmission unbalance in percent,

$V_2$ = vector voltage across half of the terminating resistor in volts, and

$V_1$ = vector voltage across the outer half of the terminating resistor in volts.

**6.16.1** *Specimen* — The specimen to be measured shall be approximately 30 m in length.

**6.16.2** *Equipment* — The accuracy of the measuring equipment shall be ±2 percent over the test frequency. Figure 7 shows a block diagram of the transmission unbalance test equipment.

**6.16.3** *Measurement* — The input transformer transmits two signals which are vectorially equal down the two-conductor line. The signal from detector on the output transformer is the magnitude of the vector difference of the voltages across each half of the terminating resistor, and the signal from detector 2 is the magnitude of the vector sum of the two voltages. The oscilloscope has logarithmic vertical amplifiers that allow the measurement of the ratio of the signals from the two detectors, expressed in decibels as follows:

$$\text{TUB ( percent )} = 200 \Big/ \left[ \text{Antilog}_{10} \times \left( \frac{\text{dB scope}}{20} \right) \right]$$

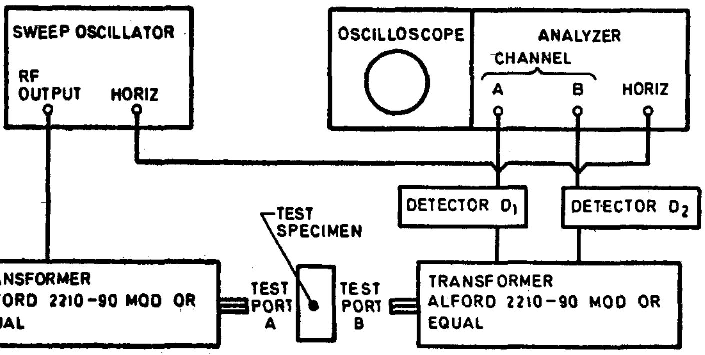

FIG. 7 BLOCK DIAGRAM OF TRANSMISSION UNBALANCE TEST EQUIPMENT

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*When specially required.

The residual error of the tests system may be obtained by removing the sample, connecting the respective test ports and measuring the system unbalance.

*Requirement* — The maximum unbalance of the specimen shall not exceed the value specified in detail specification.

**6.16.4** *Calibration of Transmission Unbalance System* – Calibration shall be performed as follows:

a) Connect test port A to test port B.

b) Switch on the frequency markers of the sweep oscillator. Connect channel A of detector 2 to the generator video input, and the generator vertical to the scope channel A port. By varying the frequency dial and sweep width controls of the sweep oscillator, obtain the required test frequency range.

c) Remove detector 1 from detector port *P* and replace it with a 50-ohm load. Connect channel A to detector 2 of the scope.

d) Obtain a signal from detector 2 on channel A. Trace this signal on the scope screen. Preset channel A attenuator to zero.

e) Insert a 10-dB pad between detector port 2 and detector 2.

f) Adjust channel A attenuator so that the average of the scope display and traced line are equal.

g) Insert a 20-dB pad between detector port 2 and detector 2. Draw the trace on the face of the scope.

h) Remove detector 2 from detector port 2, and replace it with detector 1. Connect the lead from detector to channel B vertical input.

j) Obtain trace from detector 1 by inserting a 20-dB pad between detector and connecting port. The frequency tracking of the two-detector should not vary more than ±0·5 dB.

k) Repeat steps (d), (e) and (f) with detector 1 connected to detector port 2. The lead from detector 1 must be connected to the channel B vertical input of the scope.

m) Return detectors to their original positions.

**6.16.5** *Measurement Procedure for Transmission Unbalance System* — Measurements shall be performed as follows:

a) Prepare specimen and instal applicable connectors.

b) Connect specimen between test port A and test port B.

c) Preset variable attenuators A and B to zero.

d) Switch the display control of the scope to channel A and B position.

e) Using the channel A variable attenuator, position the channel A trace at the centre of the scope screen.

f) Using the channel B variable attenuator, position the channel B trace so that it covers the channel A trace.

g) The difference, in dB, of the channel A and B variable attenuators is the unbalance of the two signals.

h) Convert the dB difference of channel A and B to the percentage of transmission unbalance by using Table 5.

TABLE 5 RELATIONSHIP BETWEEN TRANSMISSION UNBALANCE AND THE DIFFERENCE IN SIGNALS

| Transmission Unbalance | Difference in Signal | Transmission Unbalance | Difference in Signal | Transmission Unbalance | Difference in Signal |
|---|---|---|---|---|---|
| Percent | dB | Percent | dB | Percent | dB |
| 2 | 40·0 | 12 | 24·5 | 22 | 19·0 |
| 3 | 36·0 | 13 | 24·0 | 23 | 16·9 |
| 4 | 34·0 | 14 | 23·0 | 24 | 18·4 |
| 5 | 32·0 | 15 | 22·5 | 25 | 18·0 |
| 6 | 30·0 | 16 | 22·0 | 26 | 17·8 |
| 7 | 29·0 | 17 | 21·5 | 27 | 17·4 |
| 8 | 28·0 | 18 | 21·0 | 28 | 17·0 |
| 9 | 27·0 | 19 | 20·5 | 29 | 16·8 |
| 10 | 26·0 | 20 | 20·0 | 30 | 16·4 |
| 11 | 25·6 | 21 | 19·5 | | |

**6.17 Mechanically Induced Noise ( For Low Noise Cables Only )** — The electrical noise generated in a cable by mechanical motion shall be determined by the following test.

**6.17.1** *Preparation of Cable* — Cut cables to be tested into 2 m lengths. Fit one end of cable with a suitable connector. Remove 5 cm of the outer jacket from the other end of the cable leaving the braid intact. Push braid back and cut-off 25 mm of the dielectric and centre conductor. Cover the open end with three layers of electrical tape. Pull braid over the tape. Twist and solder to form an interference shield.

**6.17.2** *Instrumentation*

a) *Amplifier*

1) Input impedance — 10 megohms, minimum.

2) Frequency response — dc to 1 megahertz, minimum.

3) Sensitivity — 10 microvolts/centimetre, minimum.

b) *Oscilloscope*

c) *Recorder*

1) For digital, storage scope with X-Y output to X-Y recorder.

2) For non-digital, storage scope oscilloscope camera.

d) Appropriate weight with cable clamp — 4·5 N for cables up to 5 mm in diameter and a 26 N for cable over 5 mm in diameter.

e) Six cable clamps of suitable size and circumferential compression type.

f) Suitable cable connector for interfacing with amplifier.

**6.17.3** *Equipment Set-up* ( *see* Fig. 8 ) — Clamp the cable in place so that the interference shield is just beyond three of the clamps and the inside clamps are 1·2 m apart and such that 1·5 m of slacked cable hangs freely between the support. Clamp the weight midspan of cable ( that is, 75 cm from either end of the 1·5 m of cable supported between the clamps ). Connect the cable to be tested to the amplifier and oscilloscope. Shield as necessary to prevent noise pick-up.

**6.17.4** *Calibration of Instruments* — Set the gain of the amplifier so that the specified maximum peak-to-peak noise can be easily determined. Calibrate the amplifier and oscilloscope for an accuracy of ±5 percent. Set the oscilloscope in the single sweep made with a sweep speed of 1 cm per second and the sensitivity to 10 $\mu$V/cm, lower frequency 3 dB response to 0·1 Hz, upper frequency 3 dB response to 10 kHz.

**6.17.5** *Test Procedure* — Pull cable through 90° or until cable, weight and clamp are in a horizontal plane. If a camera is used, open the camera shutter, trigger the sweep and release the weight. A mechanical release device may be used, if desired to assure repeatability of the measurements. Repeat this procedure until eight individual sweeps have been recorded.

*Requirement* — The mechanically induced noise voltage shall not exceed the value specified in detail specification.

**6.18 Time Delay***

**6.18.1** *Specimen* — Two specimens shall be tested for time delay. The test frequency shall be as specified. The length of the specimen shall be determined from the following formula:

$$L = \frac{300}{f\sqrt{e}}$$

where

$L$ = specimen length, in metre;

$f$ = specified frequency, in MHz; and

$e$ = dielectric constant of cable dielectric core.

**6.18.2** *Procedure* — The time delay measurement shall be performed as follows. The specimen shall be connected to the measurement apparatus shown in the block diagram of Fig. 9. The characteristic impedances of the specimen, the signal generator, the frequency counter, and the load impedance ( $Z_0$ ) shall be identical. All interconnections shall be as short and free of electrical mismatch as possible. The signal generator shall be set to a frequency, that is five times the specified frequency and varied until a Lissajous pattern on the screen of the oscilloscope forms a straight line. The positions of the signal generator and $Z_0$ shall then be reversed and the oscilloscope screen observed. If a straight line is not now present, adjust the interconnections until a straight line is formed for both the normal and reversed positions of the signal generator and $Z_0$.

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*When specially required.

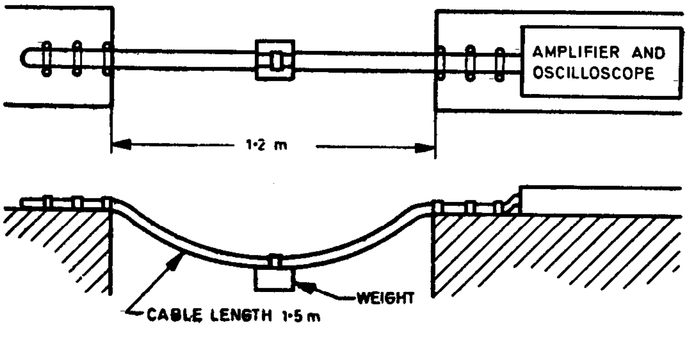

FIG. 8 EQUIPMENT SET-UP

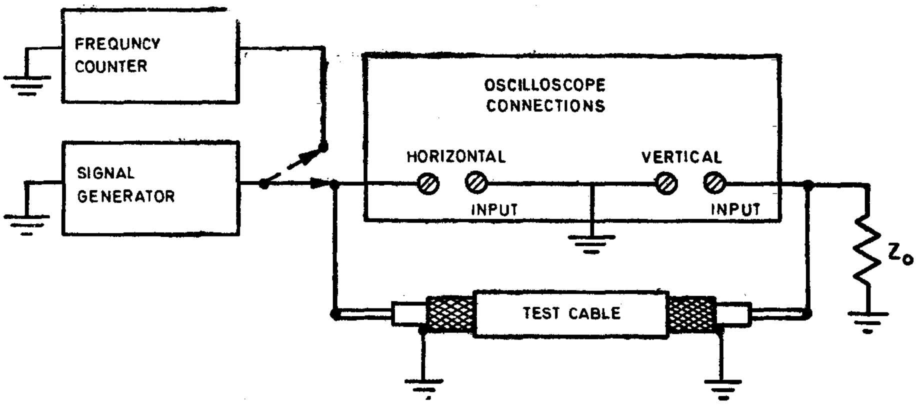

Fig. 9 Block Diagram of Apparatus for Measuring Time Delay

Go back to the original position by repositioning the apparatus as orignally shown in the block diagram. Reset the frequency of the signal generator to the specified frequency and vary it until the Lissajous pattern displayed on the screen of the oscilloscope forms a straight line. The thickness of this line shall not exceed 0·25 mm to establish good resolution. A frequency counter shall then be temporarily inserted, as shown in the block diagram, to determine the exact frequency of the signal generator. This frequency shall then be recorded as the first resonance frequency ( $f_1$ ). The frequency counter shall be removed and the frequency of the signal generator shall be increased until the Lissajous pattern forms yet another line on the oscilloscope screen with the same direction as the first line. Again, the thickness of the line shall not exceed 0·25 mm. The frequency counter shall again be temporarily inserted to determine the second resonance frequency ( $f_2$ ). This procedure shall be repeated until five successive frequencies have been determined. The time delay per foot of the cable shall then be computed as shown in the formula given below. Beginning withthe specified frequency, successive frequencies shall be determined using this method.

$$\text{TD} = \left\{ \frac{1}{f_1} + \frac{2}{f_2} + \frac{3}{f_3} + \frac{4}{f_4} + \frac{5}{f_5} \right\} \frac{1}{5\,L}$$

where

TD = time delay in microseconds per metre,

$f_1$, $f_2$, $f_3$, $f_4$, $f_5$ = recorded frequencies in MHz, and

$L$ = specimen length in metre.

The time delay shall be calculated for at least two sets of five successive recorded frequencies for each specimen. The average of these values computed shall be within the specified requirement. The specimen shall be reversed and the test repeated.

*Requirement* — The time delay shall be as specified in detail specification.

**6.19 Ageing Stability ( Not Applicable to Semirigid or Cables with Type IX Jackets )**

**6.19.1** *Specimen* — Four specimens shall be cut from the sample unit. For cables whose nominal jacket diameter is less than 12 mm, the specimen length shall be 125 times the cable diameter. For cables whose nominal jacket diameter is 12 mm or larger, the specimen length shall be 95 times the cable diameter. For armoured cables, the armour shall be removed before the specimen is subjected to the ageing stability test.

**6.19.2** *Procedure* — The specimen shall be coiled to a diameter not less than 30 times the nominal outside diameter of the cable and suspended in a heat chamber without touching one another or the walls of the chamber and conditioned for 7 days at the applicable test temperature given in Table 6. Test temperatures for cable jacket types not listed in Table 6 shall be as specified. Heated air shall be circulated so as to maintain a uniform test temperature. After the conditioning period, the specimens shall be removed from the heat chamber and conditioned at room ambient temperature for 4 hours minimum.

a) Examine the specimen for cracks, flaws or other damage in the jacket material. For marked cables, examine the marking for legibility.

b) Following the test, the specimen shall be subjected to the cold bend test ( *see* **6.23** ).

TABLE 6 JACKET TEST TEMPERATURE

| Jacket Types | Temperature, °C |
|---|---|
| I, IIa, IV and VIII | +98 ±2 |
| IIIa | 90 ±2 |
| V and VII | +250 ±5 |
| VI | +200 ±5 |

*Requirement* — There shall be no evidence of cracks, flaws or other damage in the jacket material.

**6.20 Stress-crack Resistance** *( **FEP Jacket** )

**6.20.1** *Specimen* – Four specimens, approximately 1 m long, shall be cut from the sample unit. For armoured cables, the armour shall be removed before the specimen is subjected to the stress-crack resistance test.

**6.20.2** *Procedure* — Clamp one end of each specimen to a mandrel whose diameter is three times the nominal jacket diameter of the cable, unless otherwise specified around the mandrel and clamp the specimen to the mandrel at this point. The specimens shall be suspended in a heat chamber without touching one another or the walls of the chamber and conditioned for 96 hours minimum at +230 ±5°C. Heated air shall be circulated so as to maintain a uniform test temperature. After the conditioning period, the specimen shall be removed from the heat chamber and conditioned at room temperature for 4 hours minimum.

a) Examine the specimen for cracks, flaws or other damage in the jacket material. For marked cables, examine the marking for legibility.

b) Unwind the specimen from the mandrel and examine for cracks, flaws or other damage in the jacket material. For marked cables, examine the marking for legibility.

c) After the stress-crack resistance test, the specimen shall be subjected to the cold bend test ( *see* **23** ).

*Requirement* — There shall be no evidence of cracks, flaws or other damage in the jacket material.

**6.21 Outer Conductor Integrity** *( **Only Semi-rigid Cables** ) — Four specimens, approximately 60 cm long, shall be cut from the sample unit. The specimens shall be suspended in a heat chamber without touching one another or the walls of the chamber and conditioned for 1–1/2 hours minimum at the specified temperature. Heated air shall be circulated so as to maintain a uniform test temperature. After the conditioning period, the specimens shall be removed from the heat chamber and conditioned at room ambient temperature for 4 hours minimum. Examine the specimens for cracks, flaws or other damage in the outer conductor material.

*Requirement* — There shall be no evidence of cracks, flaws or other damage in the outer conductor material.

**6.22 Screening Efficiency**

**6.22.1** *General* — The screening efficiency of a radio frequency cable depends both on the screening against currents and the screening against voltages.

The screening efficiency against currents is specified in terms of the transfer impedance due to resistive and magnetic coupling per unit length against voltages in terms of the transfer admittance due to electric coupling per unit length. Transfer impedance is defined in an elementary length of cable as the ratio of the voltage measured along the screen in the disturbed system to the current flowing in the interfering system. This may be of interest at any frequency up to 10 000 MHz. In general, there is no problem where homogeneous cylindrical shields are used since the screening effect in such cases can be readily calculated but, where a braided or taped construction is employed, it becomes necessary to measure the screening efficiency. The present state of experience shows that the surface transfer impedance remains constant at frequencies from 0 Hz to 0·1 MHz, depending on the type of cable and is equal to the direct current resistance of the screen. At frequencies over 0·1 MHz or 1 MHz, the transfer impedance increases. Depending on the construction of the screen, this increase starts directly or after having passed through a minimum.

Over 10 to 15 MHz, the increase is proportional to the frequency.

Transfer admittance is defined in an elementary length of cable as the ratio of the current flowing into the disturbed system to the voltage originating it in the specified interfering system. Measurements show that the transfer admittance may be represented by a capacitance which is independent of frequency from audio frequencies up to 1 000 MHz at least.

**6.22.2** *Transfer Impedance Due to Resistive and Magnetic Coupling*

**6.22.2.1** *Test apparatus* — The apparatus is of the 'triple coaxial' form (*see* Fig. 10). A short length of the cylindrical screen under investigation forms both the inner conductor of an energized coaxial system and, at the same time, the outer conductor of another coaxial line. The signal in the inner coaxial system is caused by the surface transfer impedance of the screen.

The cable with the screen to be measured is terminated at one end by a resistance, the value of which is numerically equal to the characteristic impedance of the cable. The terminal resistance is shielded by a metal sleeve whose edge at the open end is soldered to the screen. Terminal resistance and cable are coaxially mounted inside a metal tube. This tube is terminated at the side opposite the resistance by a short-circuiting disk which is soldered to the screen (*see* Fig. 10).

The length of the cable piece in the metal tube

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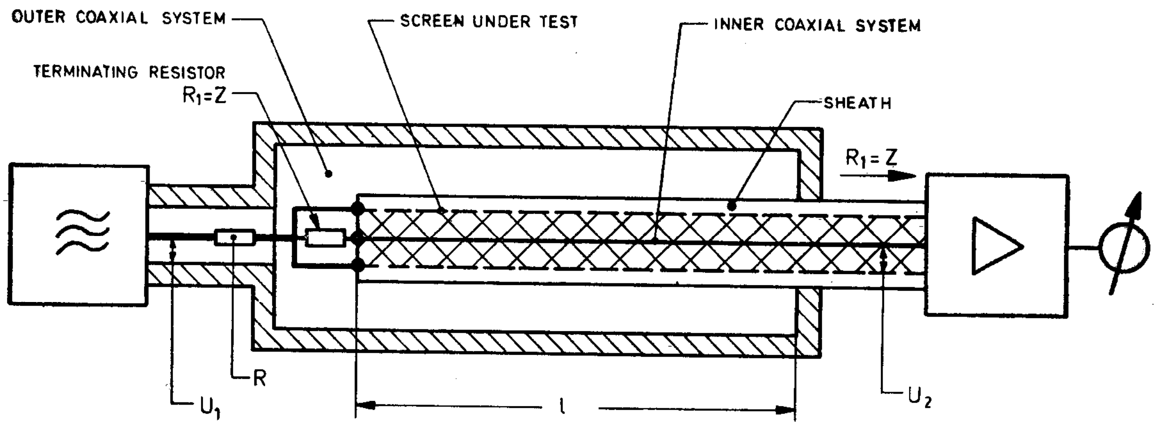
*When specially required.



NOTE — For the measurements of electric coupling, the sheath should be removed from the cable as the field strength at the outer conductor is seriously affected by the sheath.

FIG. 10 MEASUREMENT OF TRANSFER IMPEDANCE

is not to exceed 0·12 to 0·35 $\lambda$ according to the measuring equipment used. The length of the projecting cable is of no consequence.

**6.22.2.2** *Test procedure* — The outer coaxial system formed by the screen under investigation and the metal tube is fed from a generator through an interconnected resistance (Method 1) or by way of a direct connection (Method 2).

The measurement shall be carried out at 30 MHz.

NOTE — For both methods, a cable length of 1 m is mostly adequate. The correction factor at 30 MHz is approximately 1.

a) *Method 1 : Feeding through a resistance* — The generator feeds the outer system through a pure resistance ($R$) which, to the best advantage, should be equal to about 1·4 times the value of the characteristic impedance of the outer system. The input voltage to the resistance is measured by means of a suitable voltmeter. The output voltage of the inner system, which is formed by the cable proper, is measured by means of a matched voltmeter.

The transfer impedance may then be calculated from the equation:

$$|Z_T| = \frac{2R}{l} \cdot \frac{U_2}{U_1} F'$$

where

$Z_T$ = transfer impedance in ohms per metre;

$R$ = feeding resistance in ohms;

$l$ = length of the screen under test in metres (*see* Fig. 10);

$U_1$ = input voltage of the outer system measured before the resistance, $R$ in volts;

$U_2$ = output voltage of the inner system measured at the end of the screen, in volts; and

$F'$ = a factor, which allows for the frequency response (*see* Fig. 11). The exact value can be calculated from the relation:

$$F' = \frac{(1 - n^2).x.\sqrt{\cos^2 x + m^2 \sin^2 x}}{\sqrt{n^2(\cos x - \cos nx)^2 + (\sin x - n \sin nx)^2}}$$

where

$m$ = $Z_1/R$, the ratio of the characteristic impedance of the outer system to the resistance $R$;

$Z_1$ = characteristic impedance of the outer system, in ohms;

$n = \frac{\lambda_1}{\lambda_2}$;

$\lambda_1$ = electrical wavelength in the outer system;

$\lambda_2$ = electrical wavelength in the inner system; and

$x = \frac{2 \pi l}{\lambda_1}$

b) *Method 2 : Direct feeding* — The transmitter feeds the outer system directly. The input voltage of this system is measured at the beginning of the screen. The output voltage of the inner system is measured as indicated above.

This method is preferable if it is necessary to operate at greater input voltages, as for instance with screens of a very high screening efficiency or with less sensitive output voltmeters. For this method, higher frequencies may be used than for the first method.

The surface transfer impedance may be calculated from the equation:

$$Z_T = 2 Z_1 . \frac{2\pi}{\lambda_1} . \frac{U_2}{U_1} . F''$$

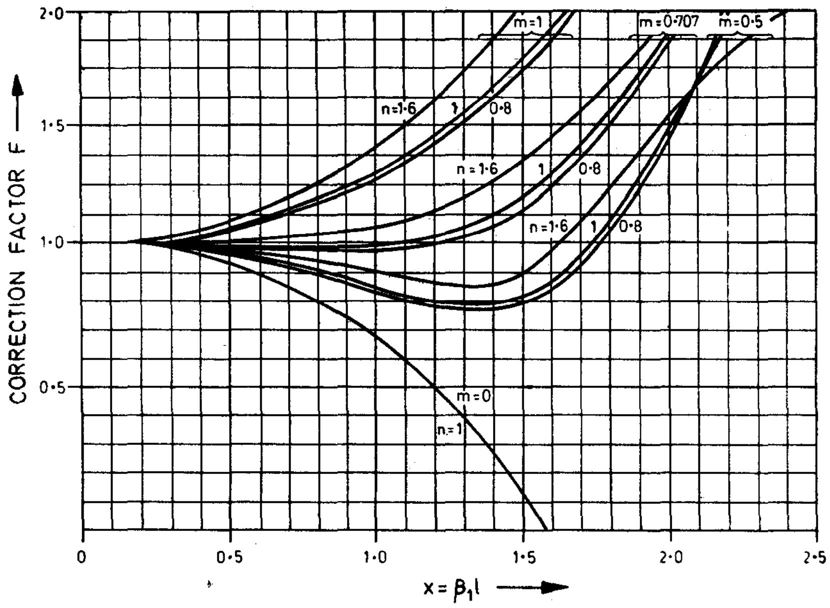


FIG. 11 MEASUREMENT OF TRANSFER IMPEDANCE

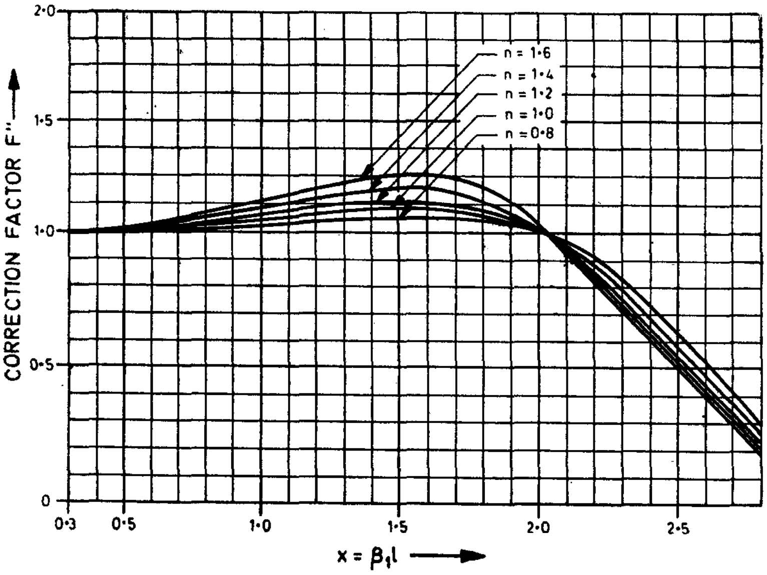


FIG. 12 MEASUREMENT OF TRANSFER IMPEDANCE

The designations of the equation have the same meaning as indicated above. $F''$ (*see* Fig.12) may be calculated from the relation:

$$F'' = \frac{(1 - n^2)\sin x}{\sqrt{n^2(\cos x - \cos nx)^2 + (\sin x - n \sin nx)^2}}$$

with the same abbreviations as above.

Instead of measuring $U_1$ and $U_2$ separately, the ratio $U_1/U_2$ may, using either method, be ascertained directly by means of a calibrated attenuator.

*Requirement* — The maximum value for transfer impedance shall be given in the detail specification.

**6.22.3** *Transfer Admittance Due to Electric Coupling*

*Method 1 : Voltage measurement*

**6.22.3.1** *Test apparatus* — The apparatus is of the 'quadruple coaxial' form (*see* Fig. 13). A short length of the cylindrical screen under investigation forms both the outer conductor of the inner coaxial system and, at the same time, the inner conductor of an energized coaxial system. The outer conductor of the energized system is

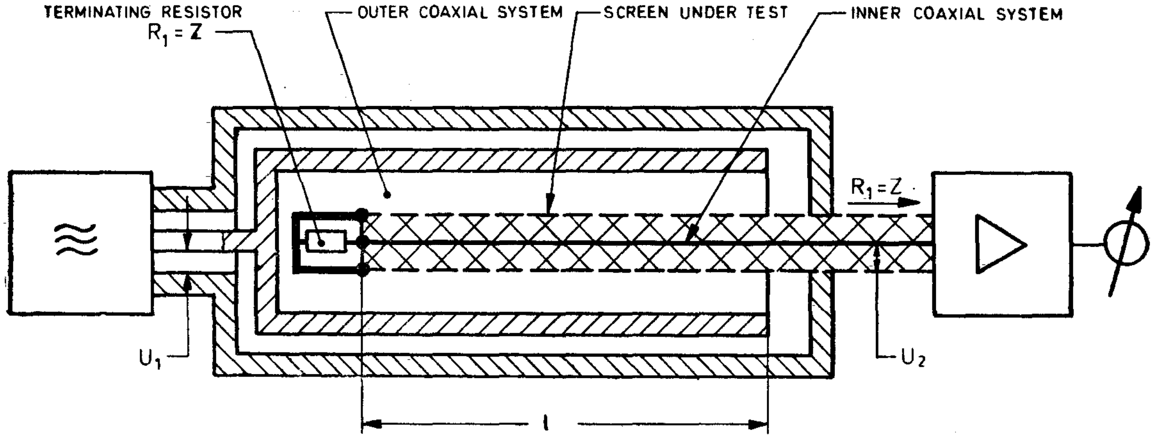


FIG. 13 MEASUREMENT OF TRANSFER ADMITTANCE

formed by a solid tube, the diameter of which is such as to give approximately the same characteristic impedance in the outer system as in the inner system, that is, the characteristic impedance of the cable with the screening under test.

The signal in the inner coaxial system is caused by the transfer admittance.

This 'triple coaxial' system is surrounded by a screen to prevent the energy from radiating out of the system, and shall not be taken into account when defining the characteristic impedance.

The cable with the screen to be measured is terminated at one end by a resistance, the value of which is numerically equal to the characteristic impedance of the cable. The terminal resistance is shielded by a metal sleeve whose edge at the open end is soldered to the screen. Terminal resistance and cable are coaxially mounted inside a metal tube, which is open-circuited at the side opposite the resistance. The whole is enclosed by the screening circuit, that is, short-circuited at the and (*see* Fig. 13).

**6.22.3.2** *Test procedure* — The outer coaxial system is fed directly from the generator. The inner coaxial system is connected directly to a matched voltmeter.

The test frequency shall be so chosen that the electrical length of the cable piece in the metal tube does not exceed 0·03 λ. The length of the projecting cable is of no consequence.

Transfer admittance at 30 MHz may be calculated from the equation:

$$|Y_T| = \left|\frac{U_2}{U_1}\right| \cdot \frac{2}{Z_2 . l} \cdot \frac{f_0}{f_m}$$

where

$Y_T$ = transfer admittance in seimens per metre at 30 MHz,

$U_1$ = input voltage of the outer system in volts,

$U_2$ = output voltage of the inner system in volts,

$Z_2$ = characteristic impedance of the cable under test,

$f_M$ = measuring frequency in megahertz;

$f_0$ = 30 MHz; and

$l$ = length of the screen in metres.

*b) Method 2 : Through capacitance measurement*

**6.22.3.3** *Test apparatus* – The apparatus is of the 'triple coaxial' form (*see* Fig. 14). The inner conductor of the cable with the screening under test is shielded at one end by means of a metal disk connected to the screen. The cable is coaxially mounted inside a metal tube. This tube is open ended at the side opposite the metal disk. The diameter of the metal tube shall be such as to give approximately the same characteristic impedance in the outer system as that of the cable under test. The screen under test shall be of sufficient length so that end-effects will have only little influence on the accuracy of the measurement.

**6.22.3.4** *Test procedure* — By means of a suitable capacitance-bridge ( *see* Fig. 15 ), the capacitance is measured between the inner conductor of the cable under test and the metal tube, while the screen is connected to the middle of the bridge. The test frequency shall be approximately 1 000 Hz.

The transfer admittance may be calculated from the equation:

$$|Y_T| = \frac{60\,\pi\,C_T 10^{-6}}{l}$$

where

$Y_T$ = transfer admittance in seimens per metre at 30 MHz,

$C_T$ = through capacitance in picofarads, and

$l$ = length of the screen under test in metres.

*Requirement* — The maximum value for transfer admittance shall be given in the detail specification.

**6.22.4** *Terminated Triaxial Test Method for Measurements of Transfer Impedance and Capacitive Coupling Impedance up to 1 000 MHz*

**6.22.4.1** *Test arrangement*

The terminated triaxial test arrangement is illustrated diagrammatically in Fig. 16, and consists of two coaxial systems terminated with balun transformers at both ends. The inner coaxial system is the coaxial cable sample being tested. The outer system consists of the screen of the cable and of an auxiliary flexible and braided or solid screen placed tightly around the jacket of the cable. It is also possible to match the propagation velocities of the outer and inner coaxial systems by replacing the jacket of the cable under test with, for example, polystyrene tube.

The balun boxes are made of electrical conducting material. In these cable sections, many ferrite toroids ( for example, 70 toroids per balun ) are placed around the ends of the cable under test in order to minimize the current flow along the outer surface of the test sample towards the ends of the balun boxes. As shown in Fig. 16, the test sample is attached to the balun section via a connector. Alternatively, the balun sections may be placed directly around the test sample which is connected directly to the $U_2$ port of the balun box. The design of the balun sections has

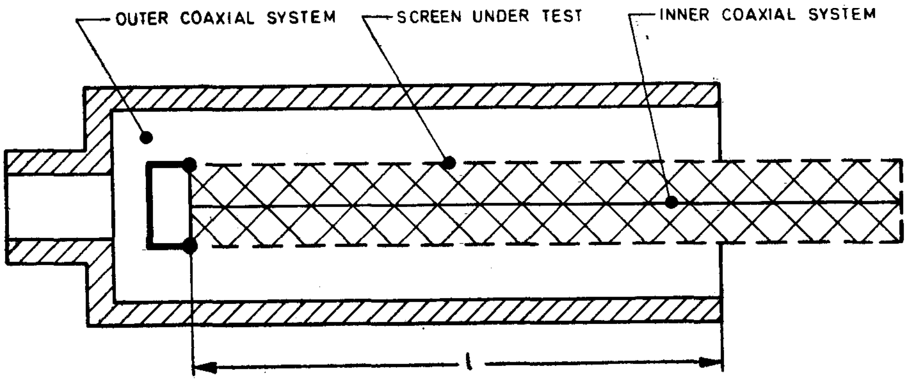


FIG. 14 MEASUREMENT OF TRANSFER ADMITTANCE

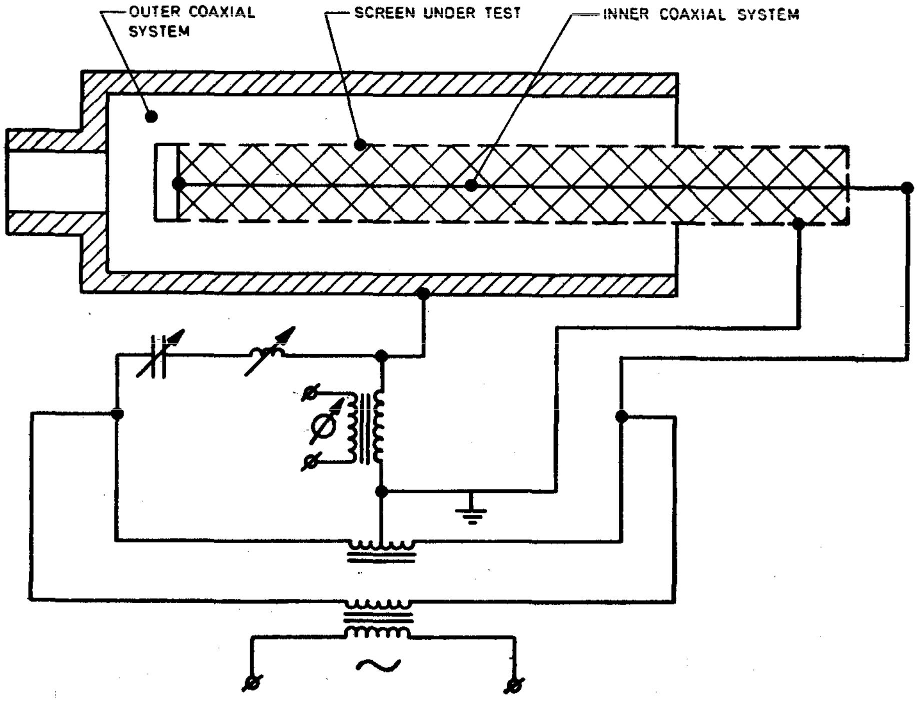


FIG. 15 MEASUREMENT OF TRANSFER ADMITTANCE

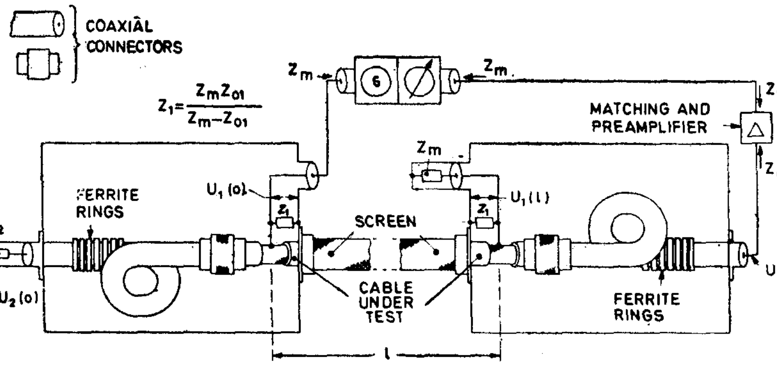


FIG. 16 ARRANGEMENT FOR $Z_T$ MEASUREMENTS UP TO 1 000 MHz

as its object the maximizing of the impedance between the screen of the cable sample and the balun box over the frequency range under consideration. The size of the balun sections and the characteristics of the ferrite toroids determine the lower frequency limit of the test arrangement.

The outer coaxial system is terminated at both ends with resistances of a suitable value to match the outer coaxial line together with the measuring equipment. The loop in the balun section eliminates the need for precisely cutting the sample to a given length.

**6.22.4.2** *Measuring the transfer impedance* $Z_T$

The voltages $U_1(l)$ and $U_2(l)$ denoted in Fig. 16 are measured by means of a suitable voltmeter. The transfer impedance may then be calculated from the equation (provided $|Z_T| \gg |Z_F|$):

$$|Z_T| = \frac{2\,Z_{01}}{l} \left| \frac{U_2(l)}{U_1(l)} \right| F$$

where

$Z_T$ = transfer impedance in ohms per metre,

$Z_{01}$ = effective matching resistance of the outer system in ohms,

$l$ = length of screen under test in metres,

$U_1(l)$ = output voltage of the outer system in volts,

$U_2(l)$ = output voltage of the inner system in volts, and

$F$ = a factor which allows for frequency response.

The value may be calculated from the relation:

$$F = \frac{l\sqrt{(\alpha_1 - \alpha_2)^2 + (\beta_1 - \beta_2)^2}}{\sqrt{(1 - e^{(\alpha_1 - \alpha_2)l}\cos(\beta_1 - \beta_2)\,l)^2 + (e^{(\alpha_1 - \alpha_2)l}\sin(\beta_1 - \beta_2)\,l)^2}}$$

where

$\alpha_1$ = attenuation of the outer system in nepers per metre,

$\alpha_2$ = attenuation of the inner system in nepers per metre,

$\beta_1$ = phase constant of the outer system in radians per metre, and

$\beta_2$ = phase constant of the inner system in radians per metre.

**6.22.4.3** *Determining the effect of capacitive coupling impedance,* $Z_F$

The capacitive coupling impedance is directly proportional to the frequency. Because of the strong effect of reflections in the outer system on the measured $Z_F$ values at high frequencies, $Z_F$ shall be measured at a frequency $f_0$ where the transfer impedance is inductive ( that is, $f_0 > 5$ MHz ) and the system length shall be such that:

$$l \leqslant \frac{\lambda_1 + \lambda_2}{20}$$

where $\lambda_1$ and $\lambda_2$ are the wavelengths of the outer and inner systems.

The valtages $U_2(0)$, $U_2(l)$ and $U_1(l)$, denoted in Fig. 16, are measured with a suitable voltmeter. The capacitive coupling impedance $Z_{F0}$ at frequency $f_0$ may then be calculated from the equation:

$$|Z_{F0}| = \left| \frac{|U_2(0)| \pm |U_2(l)|}{U_1(l)} \right| \frac{Z_{01}}{l}$$

where the — sign applies, when $|Z_T| > |Z_F|$ and the + sign applies, when $|Z_T| < |Z_F|$.

The value of the capacitive coupling impedance may then be calculated at any frequency from the equation:

$$|Z_F| = \frac{f}{f_0} |Z_{F0}|$$

Now the value of the transfer impedance may be calculated from the equation ( at frequencies $> 5$ MHz ):

$$| Z_T | = \left| 2 \left| \frac{U_2 (l)}{U_1 (l)} \right| \frac{Z_{01}}{l} F \pm | Z_F | \right|,$$

where the + sign applies when at the frequency $f_0$:

$| U_2 (0) | > | U_2 (l) |$ and $| Z_T | > | Z_F |$

and the − sign in all other cases.

NOTE 1 — For most RF cables $| Z_T | > | Z_F |$. However, if there is any doubt whether this applies, the phase of the voltage $U_2$ (0) or $U_2$ ($l$) ( whichever voltage is smaller ) should be measured relative to the voltage $U_1$ ($l$). If this phase is about 90°, $| Z_T | > | Z_F |$ if about —90° $| Z_T | < | Z_F |$.

When measuring the phase, the measuring cables, including the cables inside the boxes, should have an equal electrical length.

NOTE 2 — The return losses of the terminations in the outer circuit should be better than 20 dB at frequency $f_0$. At higher frequencies, the return losses of the terminations in the outer and inner circuits should be so high that the measurements are not disturbed by the reflections.

NOTE 3 — Precautions should be taken which vary with the value of transfer impedance to be measured. These are under consideration.

**6.23 Cold Bend* (Not Applicable to Semi-rigid Cables)** — Three specimens shall be cut from the sample unit. The specimen lengths shall be the same as for the ageing stability, stress-crack resistance and other outer conductor integrity tests, as applicable ( *see* **6.19**, **6.20** and **6.21** ). The distance between the cable turns wrapped on the mandrel shall not be more than the diameter of the cable; the cable shall make intimate contact with the mandrel.

**6.23.1** *Flexible Cables*

a) For armoured cables, the armour shall be removed before the specimen is subjected to the cold bend test. One end of each specimen shall be clamped on a mandrel whose diameter is 10 times the normal outside diameter of the specimen in its present test condition. Wrap the specimen around the mandrel for one full turn and hold in place with a mechanical device. The specimens shall be placed in a cold chamber and conditioned for 20 hours minimum at the applicable test temperature. During the conditioning period, the unwraped portion of the specimen shall be kept reasonably straight. The following details shall apply:

  1) For cables with Type F dielectric cores, cables with Type IIIa jackets, and cables whose nominal jacket diameter is 6 mm or smaller, the test temperature shall be −55 ±2°C.

  2) For those other cables whose nominal jacket diameter is larger than 6 mm, the test temperature shall be —40 ±2°C. For those cables that have been previously subjected to the ageing stability test, the test temperature shall be −35 ±2°C.

b) After the conditioning period and while the specimens are still at the test temperature, the specimens shall be wrapped around the mandrel for three full close turns for cables whose nominal outside diameter is less than 12 mm, or two full close turns for cables whose nominal outside diameter is 12 mm or larger. The mandrel shall be turned at a uniform rate of 15 ± 3 revolutions per minute during this operation.

c) After the turning operation, the specimen shall be removed from the cold chamber and conditioned at room ambient temperature for 1 hour maximum.

Unwind the specimen from the mandrel and, except at the clamping points, examine for cracks, flaws or other damage in the outer surface material.

*Requirement* — There shall be no evidence of cracks, flaws or other damage in the jacket material of flexible cables or the dielectric core material of flexible cable.

**6.24 Flow Test**

**6.24.1** This test determines the resistance of the dielectric to mechanical distortion at high temperature. For convenience, the displacement of the inner conductor, when loaded as in **6.24.1.1**, is taken as an arbitrary measure of the plastic flow to be expected when the cable dielectric is subject to mechanical stress at high temperatures.

This test shall be carried out in accordance with IS : 9000 ( Part 3 )-1977*.

**6.24.1.1** A length of cable, thirty times the outer diameter of the cable, shall be submitted to a temperature of 98 ± 2°C for a period of 7½ h. During this time, a weight, as specified in the detail specification, shall be attached to each end of the inner conductor after skinning at least 25 mm at each end of a coaxial cable or each end of the joined inner conductors of a twin conductors cable. The whole cable shall be bent symmetrically with the weights hanging free over a horizontal test mandrel with a diameter of approximately ten times the outer diameter of the cable.

**6.24.1.2** At the end of this period, the weights shall be removed and the cable shall be removed from the oven and, without bending, allowed to cool for 1 h under standard atmospheric conditions for testing.

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*When specially required.

*Basic environmental testing procedures for electronic and electrical items: Part 3 Dry heat test.

*Requirement* — The inner conductor of a coaxial cable shall not be displaced from the centre by a distance greater than 15 percent of the nominal diameter of the dielectric measured along the direction of flow. The distance between either conductor of a twin cable and the shield shall be not less than that specified in the detail specification.

### 6.25 Dimensional Stability ( Not Applicable to Time Delay Cables and Cables with Braided Inner Conductor )

**6.25.1** *Flexible Cables* — A 1·5 m minimum specimen shall be cut from the sample unit. The ends of the specimen shall be cut squarely and carefully deburred. Place the specimen in a heat chamber, coiled to a diameter not less than approximately 30 times the maximum outer diameter of the cable or straight, and condition for 6 hours minimum at the applicable test temperature ( *see* Table 7 ). Heated air shall be circulated to maintain a uniform test temperature. After the conditioning period, remove the specimen from the heat chamber and condition at room ambient temperature for 4 hours minimum. Measure both ends of the specimen for protrusion or contraction of the inner conductor.

TABLE 7 MATERIAL AND TEST TEMPERATURES

| MATERIAL TYPES | TEMPERATURE*, °C |
|---|---|
| Type A dielectric | +85 ±2 |
| Type F dielectric ( except with Type IX jacket ) | +250 ±5 |
| Type F dielectric with Type IX jacket | +200 ±5 |

*Test temperature for cable types not listed shall be as specified.

**6.25.1.1** A suggested method of conducting this test is as follows:

The test sample shall be coiled at the interior surface of an open cylindrical container having a diameter of approximately 30 times the maximum outer diameter of the cable ( *see* Fig. 17 ). It shall be applied in such a way that no means of fixation will be used to keep it in its position. After coiling, it shall be checked that the inner conductor and the dielectric are in the same plane at both ends of the cable. The container with the cable shall then be placed in a chamber having a temperature as called for in the detail specification and be kept at that temperature for a period of 20 hours.

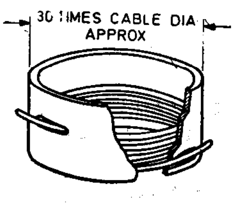

FIG. 17 DIMENSIONAL STABILITY

NOTE — Where necessary, for practical reasons, one sample shall be put in the container at a time.

At the end of the period specified above the cable shall be removed from the chamber and allowed to cool to room temperature.

Without uncoiling the samples, the displacement of the dielectric with respect to the inner conductor shall be measured at both ends. The average of the measurements shall be calculated and conform to the values given in the detail specification.

**6.25.2** *Semi-rigid Cables*

a) *Specimen* — An appropriate 1·2 m length shall be cut from the sample unit and used to prepare six specimens. Each specimen shall have a length of 160 + 5 mm with squared and carefully deburred ends. Each specimen shall be placed inside a brass test fixture as shown in Fig. 18.

b) *Procedure* — After insertion of the specimen, the fixture ends shall be closed with caps; the caps shall be tightened with a torque of 4·0 ± 0·5 Nm. Place the fixtures containing the captured specimens in a heat chamber and condition for at least 1 hour at the specified temperature. Heated air shall be circulated so as to maintain the test temperature within ±5°C. After the conditioning period, the fixtures containing the specimens shall be maintained at room ambient temperature for at least 1 hour. Do not remove specimens from the test fixtures until immediately before measuring, and then remove one at a time. Measure the protrusion or contraction of the insulation with respect to the outer conductor on both specimen ends. Three measurements shall be made at each end, one in each of three different axial specimen orientations spaced approximately 120° apart, so that a total of six measurements are obtained for each specimen.

*Requirement* — The measurement at each end shall not exceed the value specified in the detail specification.

### 6.26 Contamination* ( PVC Type IIa Jacket Cable Only )

**6.26.1** *Specimen* — The specimen length shall

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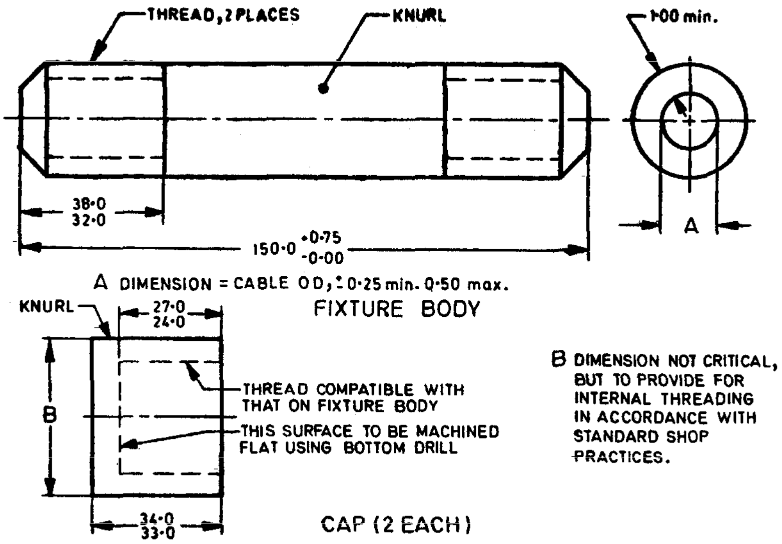
*Where specially required.


THREAD, 2 PLACES
KNURL
1·00 min.
38·0
32·0
150·0 +0·75 -0·00
A
A DIMENSION = CABLE OD, + 0·25 min. 0·50 max.
FIXTURE BODY
KNURL
27·0
24·0
B
THREAD COMPATIBLE WITH THAT ON FIXTURE BODY
THIS SURFACE TO BE MACHINED FLAT USING BOTTOM DRILL
B DIMENSION NOT CRITICAL, BUT TO PROVIDE FOR INTERNAL THREADING IN ACCORDANCE WITH STANDARD SHOP PRACTICES.
34·0
33·0
CAP (2 EACH)

All dimensions in millimetres.

FIG. 18 TYPICAL DIMENSION STABILITY TEST FIXTURE

be 1·2 m minimum for cables whose nominal outside diameter is more than 5 mm, 1 m minimum for cables whose diameter is from 3 to 5 mm, and 0·5 m minimum for cables whose diameter is less than 3 mm.

**6.26.2** *Equipment* — Equipment for the contamination test shall be a $Q$-meter with an appropriate coil capable of giving an indicated $Q$-reading of 150 minimum. The resonating test frequency for all measurements shall be 1·2 MHz ± 50 kHz. Resonate the $Q$-meter to determine its $Q$-reading ( $Q_1$ ).

**6.26.3** *Procedure* — One end of the specimen shall be cut square. The other end shall be prepared to provide the shortest possible connection to the 'high' terminal of the $Q$-meter. The shield shall be connected to the 'ground' terminal. After attaching the specimen, resonate the $Q$-meter and take the new $Q$-reading ($Q_2$). This initial change in $Q$-readings ( $\Delta Q_i$ ) between the readings with and without the specimen attached shall be computed as $\Delta Q_i = Q_1 - Q_2$. If the initial change in $Q$ ( $\Delta Q_i$ ) is less than three when using the specified length, the length may be increased so as to obtain a $\Delta Q_i$ of at least three. The specimen shall then be placed in a heat chamber and conditioned at +98° ± 2°C for 7 days minimum. Heated air shall be circulated so as to maintain a uniform test temperature. After the conditioning period, the specimen shall be removed from the heat chamber and conditioned at room ambient temperature for 1 hour minimum. Again, with the specimen unattached, take a new $Q$-reading ( $Q_3$ ). Attach the specimen as before and take another $Q$-reading ( $Q_4$ ). This final change in $Q$-readings ( $\Delta Q_f$ ) between the readings with and without the specimen attached shall be computed as $\Delta Q_f = Q_3 - Q_4$.

*Requirement* — The change in $\Delta Q$ ( $\Delta Q_f - \Delta Q_i$ ) shall not exceed 2·5.

**6.27 Bendability*** **( Semi-rigid Cable Only )** — Two specimens, each approximately 30 cm, shall be cut from the sample unit. The middle section of the specimen shall be formed for two complete turns around a mandrel of specified diameter. ( Although no special tools are needed to guide the cable as it coils around the mandrel, a mechanism may be provided so as to avoid any damage to the outer conductor ). Remove the coiled specimen from the mandrel and examine the outer surface for cracks, splits, fracturing and wrinkling.

*Requirement* — There shall be no cracks, splits fracturing, wrinkling or other damage in the solid outer conductor material, after being formed around the mandrel diameter specified in the detail specification.

### 6.28 Flammability*

**6.28.1** *Apparatus* — The test shall be performed within a test chamber approximately 30 cm square by 60 cm in height, open at top and front to provide adequate ventilation for combustion but to prevent drafts. The specimen holder shall be designed so that the lower end of a 60 cm cable specimen, as held by a clamp, while the upper end of the specimen passes over a pulley and can be suitably weighted to hold the specimen taut at an angle of 60 degrees with the horizontal, and in a plane parallel to and approximately 15 cm from the back of the chamber. The separation between clamp and pulley shall be such that a minimum of 50 cm of the specimen is freely suspended. The test flame shall originate from a Bunsen type gas burner with a 6 mm inlet, a needle valve in the base for gas adjustment 10 mm bore nominal, and an approximate 10 cm barrel length above the air inlets. The burner shall be adjusted to furnish a 7·5 cm conical flame with an approximate 2·5 cm long inner core and a flame temperature not less than 954°C at its hottest point, as measured with an accurate 1 percent full scale thermocouple pyrometer. A sheet of facial tissue shall be suspended taut and horizontal 24 cm below the point of application of the flame to the cable specimen and at least 12 mm from the chamber floor so that any material dripping from the cable specimens shall fall upon the tissue.

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*Where specially required.

**6.28.2** *Procedure* — A 60 cm specimen of cable shall be marked at a distance of 20 cm from its lower end to indicate the point for flame application and placed in the specified 60-degree position in the test chamber. The lower end of the specimen shall be clamped in position in the specimen holder and the upper end shall be passed over the pulley of the holder and held taut. With the burner held perpendicular to the specimen and at an angle of 30 degrees from the vertical plane of the specimen, the hottest portion of the flame shall be applied to the lower side of the cable at the test mark. The test flame shall be applied for 30 seconds for all sizes of cable and then withdrawn immediately at the end of that period. The distance of flame travel upward along the specimen from the test mark and the time of burning after removal of the test flame shall be recorded; also the presence or absence of flame in the facial tissue due to incendiary drip from the specimen shall be recorded. Charred holes or spots in the tissue shall be ignored in the absence of actual flame. Breaking of the cable specimens in sizes 24 and smaller shall not be considered as failure provided the requirements for flame limits, duration of flame, and absence of incendiary dripping are met.

*Requirement* — The rate of travel of the flame shall not exceed 25 mm per minute and cable surface shall not flame for more than 1 minute after the gas flame is withdrawn. There shall be no flaming of the tissue as a result of incendiary drippings from the specimen.

**6.29 Resistance to Fluids*** — This test shall be performed on cable specimens of which the overall diameter has been measured. The specimens shall be bent into single loops each having an internal diameter of approximately 14 times the overall diameter of the cable and immersed with the ends clear of the fluids, one in each of the test fluids indicated below or such fluids as agreed between the manufacturer and the purchaser at the specified temperature for a period of not less than 24 hours.

| *Fluid Represented* | *Test Fluid* | *Temperature of Test, °C* |
|---|---|---|
| Aviation turbine fuel | Kerosene | |
| Fuel | 70 percent iso-octane and 30 percent toluene by volume | 20 ± 5 |
| Hydraulic fluids | 80 percent ethylene glycol monethyl ether +20 percent castor oil by volume | 50 ± 2 |
| Ether-based lubricating oil | Under consideration | 98 ± 2 |

**6.29.1** *Recovery* — At the conclusion of the conditioning period, each cable shall be removed from the fluid, it shall be straightened, wiped and cooled to room temperature.

Within one hour after straightening, the cable shall be bent 360° around a mandrel of the same diameter as the original loop, in the same direction as the original bend. The specimen shall remain on the mandrel for one minute and then be unwound. The cable shall show no signs, to normal vision, of splitting, cracking or other deterioration and the change in diameter shall not exceed 5 percent. At the conclusion of the test, the identification of the cable shall remain effective, but a change in colour may be disregarded. In the case of cables which include a sheath of extruded polyethylene or extruded polyvinylchloride, the samples shall then be subjected to a voltage test as prescribed in **6.7**.

*Requirement* — There shall be no signs, to normal vision, of splitting cracking or other deterioration. The marking shall be legible and indelible. The change in colour may be disregarded. The change in diameter shall not exceed 5 percent.

**6.30 Solderability** — The test specimen shall be tested according to method 2 of Section 1 of IS : 9000 ( Part 18 )-1981*.

The specimens shall have their insulation removed from the conductor for a distance of 20 cm. A resin and methylated spirit flux shall be applied to the bared conductor which shall then be immersed to a length of 10 mm in the direction of its longitudinal axis into the bath. The duration of immersion shall be 4·5 to 5·5 seconds.

*Requirement* — The solder shall adhere readily and firmly to the wire. Tinning shall be completed in 4·5 to 5·5 seconds.

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*Where specially required.

*Basic environmental testing procedures for electronic and electrical items: Part 18 Solderability test.

**6.31 Weight*** — A section of cable shall be weighed on a scale that has ± 0·1 percent accuracy.

*Requirement* — The maximum weight of the completed cable construction shall be as specified in the detail specification.

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*Where specially required.

# APPENDIX A

( *Clause* 0.3 )

## NOTES

### A-1. MAXIMUM CONTINUOUS WORKING VOLTAGE

**A-1.1** The maximum continuous working voltage is that safe voltage which can be continuously applied to a coaxial cable. This voltage is limited by the onset of corona breakdown. The cable working rating is 75 percent of the corona extinction voltage rating.

### A-2. MAXIMUM OPERATING FREQUENCY

**A-2.1** Coaxial cables operate in the principal or transverse electromagnetic ( TEM ) mode. The TEM mode has not electric and magnetic fields perfectly normal to the direction of propagation. The possibility of propagation in the higher modes limits the usefulness of a coaxial cable to below the lowest higher-mode cut-off frequency. To determine a maximum operating frequency, it is necessary to derate from the cut-off frequency to forestall the operation of the cable in a mode higher than the TEM mode. Other factors that contribute to a lower operating frequency are the elements of construction of the cable and the associated connectors. The recommended maximum operating frequency takes into account all of these factors. But the user should always check the capabilities of cable and connector assembly before operating at any high frequency.

### A-3. VELOCITY OF PROPAGATION ( VP )

**A-3.1** The velocity of propagation ( VP ) is the velocity of an electric wave governed solely by the properties of the dielectric medium and the permeability of the conductor through which it is transmitted. In free space, the electromagnetic energy will travel with a speed of $3 \times 10^6$ metres per second or a 100 percent VP. In a coaxial cable with a uniform dielectric and a conductor with a relative permeability of 1, the VP is always less than 100 percent. Hence, the VP of a coaxial cable is the ratio of the speed of electromagnetic energy flow as compared to the speed of light.

$$\text{Percent VP} = \frac{\text{Velocity of energy in a cable dielectric medium}}{\text{Velocity of energy in free space}} \times 100$$

The VP in a cable may be found by resonating a length of cable at 100 MHz or more, with one end short-circuited or open-circuited in accordance with the following formula:

$$\text{Percent VP} = \frac{f_r \times \text{Cable length ( metre )}}{0{\cdot}75 \times N}$$

where

$N$ = number of quarter wavelengths in the cable specimen, and

$f_r$ = resonant frequency.

A simpler method of computing the percent VP uses the effective dielectric constant of the dielectric medium.

$$\text{Percent VP} = \frac{1}{\sqrt{e}} \times 100$$

### A-4. POWER RATING ( CW )

**A-4.1** The maximum power-handling capability, in watts, is the amount of power that a coaxial can safely transmit without overheating or developing a dielectric breakdown throughout the usable frequency range. The safe power-handling capabilities are shown on the associated curves. These curves have been derated with an assumption of a VSWR of 2, an ambient temperature range of +38 to +71°C for PE dielectric, and +38 to +149°C for PTFE dielectric, and also a maximum inner conductor temperature of +85°C for PE and +200°C for PTFE. The curves have also taken into account the effects of typical system installations ( that is, bends, clamps, thermally insulated sections, etc ).

## A-5. MINIMUM RECOMMENDED BEND MANDREL RADIUS FOR NORMAL USE

**A-5.1** The minimum recommended bend radius for a coaxial cable in normal usage is given on the specification sheet. The radius given is to the outer surface of the cable. This minimum bend radius is dependent upon the material of the outer conductor and its thickness. If possible and the attenuation requirements allow it, add a service length to the cable. Do not use tight bend radii, unless the application warrants it. Extreme care should be taken in the forming to prevent wrinkling or cracking.

## A-6. OPERATING TEMPERATURE RANGE

**A-6.1** The operating temperature range is the limits between which a cable may be operated continuously without any loss in the basic properties of the cable. This includes the ambient temperature plus the increased temperature due to inner conductor operation. This temperature range is just a guideline, since the mechanical, environmental and electrical requirements of the application contribute to the allowable temperature range. In no case should the testing temperatures be considered as the operating temperature range. Testing is usually done under accelerated conditions so as to possibly degrade the materials.

## A-7. MAXIMUM OPERATING TEMPERATURE FOR SEMI-RIGID CABLES

**A-7.1** Heating semi-rigid cables and cable assemblies to exceed specified temperatures will cause permanent increases in the outer conductor diameter. These, in turn, will increase the characteristic impedance, decrease conductor adherence capacitance and corona extinction voltage, and cause VSWR increase in cable assemblies. While effects of temporary heating during soldering processes can be minimized or eliminated, the effects of long-term heating of semi-rigid cables and cable assemblies shall be taken into consideration by the designers.

## A-8. PRECONDITIONING SEMI-RIGID CABLES

**A-8.1** The electrical and mechanical performances specified for semi-rigid cables are achieved by a compression fit between the outer conductor and the dielectic core which, in turn, necessitates manufacturing processes that cause deformation of the core by compression and elongation. The resulting stress, that is, initially non-uniform tends to equalize by cold flow within a few weeks after the manufacturing, and will cause withdrawal of the core into the cable. If this occurs in cable that has become part of a cable assembly, the resultant development of an air-void at the cable-connector interface causes VSWR increase. It is, therefore, advantageous to achieve core stress-relief by preconditioning cable before it becomes a cables assembly.

**A-8.2** Preconditioning is not effective on long lengths of cable. Bending of cable, which is usually involved in the manufacture of cable, tends to introduce non-uniform core stresses, therefore, preconditioning is more effective when performed on cable assemblies that are complete except for the final end preparation and before attaching the connector. Since preconditioning will result in withdrawal of dielectric into the cable, preparation of the cable assembly should allow for a 6 mm length on each cable end beyond the design dimension. The outer conductor and the core should not be cut to the final dimensions until preconditioning has been completed.

**A-8.3** A recommended preconditioning procedure consists of three of the following temperature cycles:

a) *Step 1* — Heat the specimen to the maximum operating temperature specified and maintain for 1 hour minimum.

b) *Step 2* — Return specimen to room ambient temperature. Trim protruding core, if any, flush with the edge of the outer conductor.

c) *Step 3* — Maintain specimen at room temperature for 1 hour minimum.

d) *Step 4* — Cool specimen to —45°C and maintain for 1 hour minimum.

e) *Step 5* — Return specimen to room temperature and maintain for 1 hour minimum.

**A-8.4** After the last temperature cycle, maintain the specimen at room temperature for 24 hours before proceeding with further processing.

**A-8.5** Recommendations for dealing with special requirments should be obtained from cable manufacturers.

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